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A MANUAL OF CHEMISTRY

BY

RICHARD D. HOBLYN A.M. Oxon.

AUTHOR OF A
TIONARY OF TERMS USED IN MEDICINE AND THE COLLATERAL SCIENCES"

ILLUSTRATED BY SEVENTY-FIVE ENGRAVINGS

LONDON
INTED FOR SCOTT, WEBSTER AND GEARY
CHARTERHOUSE SQUARE

1841

THE NEW YORK
PUBLIC LIBRARY
6228 A
ASTOR, LENOX AND
TILDEN FOUNDATIONS
R L

Printed by A. Sweeting, Bartlett's Buildings, Holborn.

ADVERTISEMENT.

THE importance of a knowledge of Chemistry is now universally admitted, not only from the extraordinary progress of the science itself, but also from its extensive influence upon the corresponding progress of nearly every Art, Science, and Manufacture. Numerous institutions have, accordingly, been established in all parts of these kingdoms for the purpose of communicating elementary instruction in this most popular branch of science. It can no longer be pretended that a liberal education may consist with an ignorance of those laws by the operation of which the order of Nature herself is preserved, the ever-varying changes of Matter are regulated, and the innumerable processes which minister to the convenience, the wants, the happiness of man, are conducted. To mention but one instance of the *wonders* opened to our view by a knowledge of this interesting science—who, in the present day, would avow his ignorance of the application of Steam to the whole science of Navigation—'that new and mighty power,' to use the eloquent language of Canning, 'new at least in the application of its might, which stalks the water like a giant rejoicing in its course—stemmin alike

the tempest and the tide—accelerating intercourse, sl
ening distances; creating, as it were, unexpected ne
bourhoods, and new combinations of social and comme
relation; and giving to the fickleness of winds, and
faithlessness of waves, the certainty and steadines
a highway upon the land?'

The present Treatise has been prepared for the
pose of affording public or private instruction in
principles of Chemistry. The most important facts
theories of the science are stated in as condens
form as the subject admits; a series of recapitula
questions is appended to each chapter for the examina
of students, according to the plan adopted in Mr. M
GILLIVRAY's Manuals of Natural History; and the Au
ventures to hope that the student may acquire from
study of this work such general information as will en
him to pursue his further inquiries with advantage.

2, Sussex Place, Regent's Park,
January, 1841.

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MANUAL OF CHEMISTRY.

INTRODUCTION.

1. It was not until the middle of the last century that Chemistry began to be numbered among the exact sciences. Many useful discoveries had, indeed, been made in earlier times by an industrious class of men, termed Alchemists; but their labours were generally devoted to the fanciful search after the 'philosopher's stone,' by which the baser metals were to be transmuted into the precious—and after a universal remedy, or 'elixir vitæ,' by which human life was to be indefinitely prolonged. The true era of Chemistry dates from the period when the researches of Dr. Black, of Lavoisier, and others, established the science upon the principles of number, weight, and measure—contributed largely to its discoveries—and taught its important applications in the arts. From that period the progress of the science has been rapid; in the early part of the present century, a new stimulus was imparted to it, by the discovery of the relations of Electricity to Chemistry; and in the present day, the progress of the science is more rapid than ever. A knowledge of Chemistry has now become an essential branch of education, not only from the numerous important advantages which it is daily conferring upon society, but from the peculiar interest which it derives from being essentially an *experimental* study. 'A clever man,' says Sir John Herschel, 'shut up alone and allowed unlimited time, might reason out for himself all the truths of mathematics, by proceeding from those simple notions of space and number of which he cannot divest himself without ceasing to

that. But he could never tell, by any effort of reasoning, what would become of a lump of sugar if immersed in water, or what impression would be produced on his eye by mixing the colours yellow and blue."*—results which can be learned only by experiment. Nor should it be supposed that *practical illustration* of the facts of chemistry is placed out of the reach of the learner. Dr. Reid well observes, in his 'Study of Chemistry,' that "though a complete and extended course of chemical experiments can be given only where the proper facilities for operating are to be met with, the introduction of a system of testing and operating upon a small scale, as a means of facilitating the progress of the student, is of the greatest practical importance. He who provides himself with a few slips of glass, a few tubes with acids and alkalies, and a small quantity of fifty or sixty of the more important chemical preparations—all of which, both apparatus and materials, he can procure for five or six shillings at the utmost—not only provides himself with a small museum to which he can continually refer, but can also perform, again and again, with a part of the materials, several thousand experiments. He can, moreover, review them at his own convenience, whenever he may be disposed, [illegible] and study them leisurely at home [illegible] repeat those which may be more complicated, till he becomes familiar with them." In illustration of these remarks may be adduced the example of Dr. Wollaston, one of the greatest chemists of the present century, [illegible] few instruments, and those so small, [illegible] accuracy. Nor should it [illegible] paper [illegible] and a piece of [illegible] discovered [illegible] and [illegible] Electricity. It is [illegible] instruments that [illegible] knowledge and skill [illegible]

[illegible]

2. *General Divisions of the Subject.*—Chemistry [illegible] name given to the science which investigates the composition of bodies, the changes which result from their [illegible] with, or separation from, each other, and the causes [illegible] regulate these changes. The precise meaning of the [illegible] Chemistry is uncertain: it is supposed to be [illegible] Arabic word denoting 'the substance of compounded bodies.' Its field of inquiry is co-extensive with [illegible] economy of nature,—all Matter, the earth [illegible] air, with their numerous and diver[illegible] subjects of investigation. The Che[illegible] those which Nature is daily [illegible] cesses, as in the gradual Wasting [illegible] or [illegible] volcan[illegible] proce[illegible] prepar[illegible] detect[illegible] of wor[illegible] Th[illegible] Natu[illegible] lightn[illegible] artifici[illegible] Chemis[illegible] forms [illegible] Heat, [illegible] *Impon*[illegible] appre[illegible] *Pond*[illegible] with [illegible] upon [illegible] organ[illegible] [illegible]

imponderable

1. Imponderable Agents.
    1. *Heat.*
    2. *Light.*
    3. *Electricity.*
2. Ponderable Bodies.
    1. *Mineral Bodies.*
        Inorganic Chemistry.
    2. *Animal and Vegetable Bodies.*
        Organic Chemistry.

3. Ponderable bodies, or those possessing weight, are commonly designated by the general term *Matter.* All material substances are composed of minute particles, called *molecules* or *atoms*, the nature of which will be more properly described under the subject of Chemical Action. The forms of matter are numerous, and subject to incessant change, owing to the reciprocal actions and combinations of these particles among themselves. The general forms under which every kind of matter may be classed, are three;—the *solid*, the *liquid*, and the *gaseous* or *aëriform;* many substances, as water, are capable of assuming each of these forms. Ponderable, or material, bodies are simple or compound. *Simple* or *Elementary* bodies are those which have not hitherto been resolved into simpler elements. *Compound bodies* are those formed by combination of the simple bodies, or elements. 1. The number of material substances considered to be *elementary*, amounts to fifty-four. Of these, very few occur in an elementary state; they are generally found associated with other bodies. Most of the elementary substances exist in the solid form; some of the more important occur in the gaseous or aëriform state; and one or two as liquids. Some of the elementary substances are found in such vast quantities, as to constitute a considerable proportion of the bulk of our globe; while others occur so rarely, and in such small quantities, as to be obtained only with great difficulty. 2. The nature and composition of *compound* bodies is ascertained by the chemical

processes of analysis and synthesis. By *analysis*, the elements of a compound body are separated from each other, as when a portion of water is separated, by means of galvanism, into the two elementary gaseous bodies, oxygen and hydrogen. By *synthesis*, these two gases are again made to combine together, by means of the electric spark, and a portion of water is again produced. The facility with which bodies enter into combination varies remarkably, some of them uniting with others most readily, while others can scarcely be made to unite at all.

4. *Subordinate Divisions* (*see Table*, p. 6).—The *Elementary bodies* may be divided into the non-metallic, and the metallic.—1. The *Non-metallic* bodies are twelve in number. Some of these agree in certain properties, but differ remarkably in others. These have a tendency to combine, not only with each other, but with almost all other substances; and their union is usually accompanied by the evolution of light and heat; hence, they are commonly called *supporters of combustion.* Some of the others, instead of supporting the combustion of other substances, are themselves combustible. From their property of generally forming acids, when combined with the supporters of combustion, they have been termed *acidifiable bases.*—2. The *Metallic* bodies are forty-two in number. They all combine with oxygen, and the results of their combination with this element furnish a means of distinguishing them into groups. Three of them, when combined with oxygen, form compounds which possess alkaline properties, and are therefore termed *metallic bases of the alkalies.* The next four form compounds which resemble earths, but are similar to the alkalies in their action; these compounds are called *alkaline earths*, and the metals which yield them are called *metallic bases of the alkaline earths.* The next six yield, by combination with oxygen, the pure earths, and are therefore called *metallic bases of the earths.* The remaining metals, when combined with oxygen, yield neither alkalies nor earths. Many of them, like some of the non-

metallic elements, form acids with this element, termed *acidifiable bases.* They may be divided int according to the effects which they produce on w red heat, and to the effects produced by heat up oxides, or combinations with oxygen. Thus, seven at a red heat, decompose water. Fourteen of the decompose water at any temperature, nor can thei be reduced to the metallic state by the sole action The remaining eight admit of having their oxides posed by a red heat. These divisions, together names of the elementary substances themselves, sented in the following table:—

I. Non-metallic Bodies.

1. *Supporters of Combustion.*

1. Oxygen
2. Chlorine
3. Bromine
4. Iodine
5. Fluorine

2. *Acidifiable Bases.*

6. Hydrogen
7. Nitrogen
8. Sulphur
9. Boron
10. Selenium
11. Phosphorus
12. Carbon

II. Metallic Bodies.

1. *Metallic bases of the Alkalies.*

13. Potassium
14. Sodium
15. Lithium

2. *Metallic bases of the Alkaline Earths.*

16. Barium
17. Strontium
18. Calcium
19. Magnesium

3. *Metallic bases of the Earths.*

20. Aluminium
21. Thorium
22. Glucinium
23. Zirconium
24. Yttrium
25. Silicium

4. *Metals which decompose water at a red heat.*

26. Manganese
27. Zinc
28. Mercury
29. Tin
30. Cadmium
31. Cobalt
32. Nickel

5. *Metals which do not decompose water at any temperature, and the oxides of which are not reduced to the metallic state by the sole action of heat.*

33. Arsenic
34. Chromium
35. Vanadium
36. Molybdenum
37. Tungsten
38. Columbium
39. Antimony
40. Uranium
41. Cerium
42. Bismuth
43. Titanium
44. Tellurium
45. Copper
46. Lead

6. *Metals, the oxides of which are decomposed by a red heat.*

47. Mercury
48. Silver
49. Gold
50. Platinum
51. Palladium
52. Rhodium
53. Osmium
54. Iridium *

These Elementary substances have been arranged by Dr. Thomson under three great divisions, which he denominates—1. The *Supporters of Combustion*;—2. The *Acidifiable Bases*;—3. The *Alkalifiable Bases.*

(1.) The *first division* consists of the substances given under that denomination in the preceding table.

(2.) The *second division* consists of the substances given under the term 'acidifiable bases' in the table, together with Silicium, Arsenic, Antimony, Tellurium, Chromium, Uranium, Vanadium, Molybdenum, Tungsten, Titanium, and Columbium.

---

* To the Class of Metals, an addition has lately been made by the discovery of Lantane, which makes the fifty-fifth elementary body.

(3.) The *third division* is subdivided into five families, viz.: the *Alkaline bases*, comprising the substances given in the table under the two first divisions of the Metallic Bodies: the *Earthy bases*, comprising Aluminium, Glucinium, Yttrium, Zirconium, Thorium, and Cerium; the *difficultly fusible bases*, comprising Iron, Manganese, Nickel, and Cobalt; the *easily fusible bases*, comprising Zinc, Cadmium, Lead, Tin, Bismuth, Copper, and Mercury; and the *noble metals*, comprising Silver, Gold, Platinum, Palladium, Rhodium, Iridium, and Osmium.

5. PROPERTIES OF MATTER.—The *Properties of Matter* are of two kinds, physical and chemical; the former of these belong to the study of Natural Philosophy, the latter to that of Chemistry. The *Physical Properties* of Matter are either *general*, belonging to all bodies; or *secondary*, belonging to certain bodies only. Of the *General Properties*, the principal are Extension, Impenetrability, Divisibility, Inertia, Attraction, and Indestructibility.

(1.) *Extension* is the property which bodies possess of occupying space, and relates to the qualities of length, breadth, and thickness, without which no substance can exist. It has no reference to size or shape. The result of extension is *figure*, or *form*, which may be determinate and regular, as a crystal; or irregular, as fluid bodies, a fragment of glass, &c.

(2.) *Impenetrability* is the property by which one body occupies a certain space, to the exclusion of every other body from that space; or, in other words, by which no two bodies can occupy the same space at the same time. A nail, driven into a board, does not *penetrate* the wood; it merely *separates* and *displaces* its particles. When salt is dissolved in water, neither of these substances is penetrated by the other; the particles of the salt are merely separated from each other, and may be again obtained in the solid form.

(3.) *Divisibility* is the property by which a body may be divided into minute parts. A grain of gold may be hammered so thin as to cover fifty square inches of surface, and present two millions of visible points. Wollaston made a gold wire so thin, that an ounce of it would extend fifty miles. One grain of a colouring substance will impart a tint to five pounds of pure water: as it is possible to render visible so small a quantity of water as a thousandth part of a grain, this portion of the mixture must contain a thirty-five millionth part of the grain of colouring matter. A single grain of musk will scent a room for several years; its particles must, therefore, have been floating in the air in every part of the room. The vegetable kingdom furnishes innumerable instances, not only of the extraordinary divisibility of matter, but also of its activity, in the almost incredibly rapid development of cellular structure in plants. Thus, the *Bovista Giganteum*, a species of fungus, has been known to acquire the size of a gourd in one night: supposing the cells to be 1-200th of an inch in diameter, they must be developed at the rate of more than 66,000,000 in a minute. Animalcules have been discovered of such smallness that a million of them do not exceed a grain of sand in size. They have circulating fluids; but what idea can we form of the minuteness of a globule of their blood?

(4.) *Inertia* is the property by which matter is incapable of putting itself in motion, or of arresting its own progress when put in motion by some force. A ball rolled on the ground soon ceases to move, owing to the impediments it meets with from the roughness of the surface, &c.; if rolled on ice with the same force, its motion continues much longer, the impediments being fewer; if projected into the air, its motion is arrested by gravity, &c.; but if it were projected into free space, where no impediments occur from air or friction, it would exhibit the phenomenon of perpetual motion.

(5.) *Attraction* is the property by which bodies tend towards each other. As it occurs between masses of matter, and operates at sensible distances, it is termed *attraction of gravitation.* The sun attracts the earth at a distance of 95,000,000 miles; the earth attracts the moon at the distance of *240,000 miles*; the moon reciprocally attracts the earth, the moveable parts of which, or the waters, und the influence of this attraction, exhibit the phenomena tides. Upon this principle, Newton founded his law universal gravitation. The effect of gravitation, as it exis on the space of our own globe, is seen in the tendency whi all bodies possess of descending in straight lines towards th centre of the earth; the force which acts in separating body from the surface of the earth, or in preventing it fro descending to the surface, is called its *weight*. As attracti occurs between the particles of a body, and operates at i sensible distances, it is termed *attraction of cohesion*, a consists in maintaining the constituent parts of a body union with each other, and resisting their separation. It generally most powerful in solids, weaker in liquids, a appears to be entirely wanting in elastic fluids, as air. T peculiar phenomena of *chemical attraction* will be fully co sidered under the subject of Chemical Action.

(6.) *Indestructibility* is the property by which matt never ceases to exist. It may change its form, and disa pear, but it is not annihilated. Water may be boiled awa and converted into invisible steam, but this may be aga condensed, and restored to its former condition. Anim and vegetables die and are decomposed, but their materi furnish nutriment for other animals and vegetables; the ve refuse of matters which have served as food and clothin which taint the air, and render it pestilential, may, wh spread upon the surface of the soil, be the means of clothi it with verdure, and endowing it with fertility.

(7.) The *Secondary Properties* of matter are *transparen* and *opacity; hardness* and *softness; solidity* and *fluidit* *density* and *rarity; elasticity* and *brittleness; colour; m* *leability*, by which bodies admit of being hammered out in thin plates or leaves; *ductility*, by which they may be dra out into wire; *fusibility*, by which they are capable of bei melted by heat; and *tenacity*, by which they are capable supporting considerable weight without breaking. The last properties will be more particularly noticed in co nexion with the metals.

he *Chemical Properties* of matter, and the influence d by the physical properties on *chemical action*, will ribed in the chapter on this subject. It will be found here is no science so intimately connected with the f life, with the very life itself of man, as Chemistry. ractical application of chemical knowledge in the dis- y of *new* substances is full of interest. One instance here suffice. In the manufacture of soap, the vessel yed is found to be corroded; the scientific chemist es the corroding matter, and the result is the dis- y of one of the most singular and important chemical nts, *iodine*. "Curiosity is excited: the origin of the ubstance is traced to the sea-plants, from whose ashes incipal ingredient of soap is obtained, and ultimately sea-water itself. It is thence hunted through nature, ered in salt mines and springs, and pursued into all which have a marine origin; among the rest, into e. A medical practitioner then calls to mind a re- remedy for the cure of one of the most grievous and tly disorders to which the human species is subject— *oitre*, which infests the inhabitants of mountainous ts to an extent that, in this favoured land, we have y no experience of, and which was said to have been ally cured by the ashes of burnt sponge. Led by dication, he tries the effect of iodine on that com- and the result establishes the extraordinary fact, that ngular substance, taken as a medicine, acts with the t promptitude and energy on *goitre*, dissipating the and most inveterate in a short time, and acting as a e, or natural antagonist, against that odious defor- * The history of Chemistry is full of facts of equal ater interest and importance.

LAN OF STUDY.—The *Plan* which will be adopted in eatise will comprise three sections. The *first section* devoted to the consideration of the *Imponderable*

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[*] Herschel, ibid, p. 51.

Agents of Chemistry. The *second section* will be to the chemistry of *Inorganic Bodies.* This section w prise the laws of chemical affinity and combination, t with the chemical history of all the elementary bodi of the compounds which belong to inorganic matter. elementary bodies, oxygen performs a most promin in the operations of nature, from its tendency to c with other bodies, and from the importance of the com it forms with them: this element will, therefore, be sidered first. For the same reasons, in considering th elementary bodies, the combination of each of thes oxygen will be particularly noticed. The other com which the non-metallic substances form with each will next be considered. The metallic substances treated of, each in its individual character, and wi rence to its combinations with the non-metallic sub and with each other. The *third section* will be dev the chemistry of *Organic Bodies,* which may be divid the products of Vegetable, and those of Animal Life.

The Object of this treatise is to make the student acq with the *facts* which Chemistry is daily presenting notice; to enable him, from consideration of these f contemplate the *laws* which regulate the economy of n to stimulate him to pursue the science even into its f recesses. Let him not suppose that all has been e '*Science*,' observes Sir J. Herschel, 'in relation bilities, still remains boundless and unexplored, an the lapse of a century and a half from the era of Ne discoveries, during which every department of it h cultivated with a zeal and energy which have assure their full return, we remain in the situation in wh figured himself—standing on the shore of a wide ocea whose beach we may have culled some of those innu beautiful productions it casts up with lavish prodigali whose acquisition can be regarded as no diminution treasures that remain.'*

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* *Discourse on the Study of Natural Philosophy*, p. 3

SECTION I.

THE IMPONDERABLE AGENTS.

CHAPTER I.

OF HEAT.

eral Remarks.—The term Heat denotes, generally, *tion* experienced on touching a body of a higher re than that of the hand. But Heat appears to nstant state of motion and of interchange between odies, passing from those which are warmer to h are colder; until it finally settles into a state of *m.* If accumulated in any body, this accumulaot be preserved; the excess will pass away into ies. If, for instance, a number of substances of temperatures be introduced into an apartment, re is no actual source of heat, they will soon asame temperature. Hence it has been supposed is a material substance of a very subtil kind ex a greater or less degree in all bodies; when [illegible] d. It is termed *Caloric*, and is considered [illegible] he equation of heat. If the essential nature of [illegible] involved in mystery, many of its properties [illegible] ve been ascertained and [illegible]

- I. SOURCES OF HEAT.
- II. COMMUNICATION OF HEAT.
  - 1. *By Conduction.*
  - 2. *By Radiation.*
- III. DISTRIBUTION OF HEAT.
  - 1. *By Reflexion.*
  - 2. *By Absorption.*
  - 3. *By Transmission.*
- IV. EFFECTS OF HEAT.
  - 1. *Upon the Senses.*
  - 2. *Upon Material Objects.*
    - 1. *Upon their Bulk.*
      - 1. *Expansion and Contraction.* *The Thermometer.*
      - 2. *Change of Density.*
    - 2. *Upon their Form.*
      - 1. *Liquefaction.* } *Latent Heat.*
      - 2. *Vaporisation.* } *Latent Heat.*
      - *Evaporation.* *Ebullition.*
    - 3. *Upon their Luminousness.* *Incandescence.*
- V. SPECIFIC HEAT.

9. SOURCES OF HEAT.—Heat exists in all bodies in d
ferent degrees, not only in those which to our sensation
cold, but even in those of the lowest temperatures. T
principal *Sources of Heat* are the Sun, Electricity, Chemi
Action, and Mechanical Action. Each of these may be ill
trated by the following examples:—1. By collecting a
concentrating the rays of the *Sun* in burning-glasses,
intense degree of heat is produced. In the Palais Royal
Paris, a cannon is fired off at twelve o'clock daily, by co
centration of the sun's rays in a burning-glass; and th
indifferently, in summer and in winter. There are so
burning-glasses at Paris, 33 inches in diameter, by means

ich wood, which is both hard and wet, is kindled in a
ment, and cold water made to boil in small vessels in an
ually short period of time; metals, placed upon a plate of
na, are melted and vitrified; tiles, slates, and similar
ects, become instantly red hot, and are vitrified. By
ans of a combination of burning mirrors, considerable
ects may be produced at great distances; with 40 of
se, a board of beech wood, covered with tar, was set on
by Buffon, almost instantaneously, at the distance of
feet; with 128 mirrors, a board of pine wood, likewise
ered with tar, was set on fire at a distance of 150 feet;
bottles were melted, with 45 mirrors, at a distance of
feet; and with 117 mirrors, small pieces of money were
lted.—2. By means of *Electricity* metals may be ignited,
ed, and in some cases, if required, volatilized; gases may
united, which resist every other means employed to effect
ir union; most combustible bodies may be inflamed, as
ohol, phosphorus, gunpowder—and this indifferently,
ether the electric sparks be procured from ice, or from
l-hot iron. By the Galvanic action, which is a form of
ctricity, the most intense degree of heat hitherto known
s been procured.—3. Heat is produced by *Chemical
tion.* A familiar instance occurs in the slaking of lime:
water be poured upon a piece of well-burnt lime, it is
sorbed, and the lime appears for a short time as dry as
fore; but in a few minutes the lime swells, bursts into
eces, and becomes hotter than boiling water, while clouds
hot steam issue from it. The mixture of certain liquids
attended with the evolution of heat, as when oil of vitriol
mixed with water. If these two liquids be mixed in a
be, and a smaller tube containing alcohol be placed in
e mixture, the heat produced by the mixture is so great
to cause the alcohol in the inner tube to boil violently.
ombustion is an illustration of chemical action, and is
tended by heat, the degree of which varies with the
ture of the burning body. Thus, the temperature of the
me of carbonic oxide is very feeble, that of hydrogen
tense; a still more intense degree of heat is produced by

the combustion of oxygen and hydrogen gases, mixed in proportion in which they combine to form water. Th combination of these two gases, under a proper arrangeme constitutes the oxy-hydrogen blow-pipe. The *Orga* *Action* of air-breathing animals affords another illustrati of chemical action. Animal heat appears to result from sort of slow combustion, by which the carbon, or infla mable principle of the blood, combines with the oxygen the air in the act of respiration.—4. Heat is also a result *Mechanical Action*, as of percussion, friction, and conde sation. A piece of cold iron may be so dexterously stru by a hammer on an anvil, as to become hot, even red ho The effect of friction in producing heat is perceived rubbing of the hands for the purpose of warming them; an the practice of greasing the axles of carriage-wheels is prevent their setting fire to the wood by friction. Sava tribes are said to procure fire by rubbing pieces of dry woo together. Two pieces of ice, rubbed together, gradual melt, owing to the evolution of heat from them. It ha been found by experiment that a body never ceases to gi out heat by friction, however long the process is continue Lastly, it is possible to ignite tinder, by rapidly condensi a portion of air by means of a piston.

COMMUNICATION OF HEAT.

10. Heat is communicated between bodies in contact wit each other, or between the contiguous parts of the sam body, by *Conduction;* and between bodies at a distance fro each other, by *Radiation*.

11. *Conduction of Heat.*—If one extremity of a metalli body, as a rod of iron, be placed in a fire, the heat is gradually communicated, or *conducted*, to the other extremity

12. The Conduction of Heat is chiefly confined to *soli bodies;* and as solids vary considerably in their consistency their conducting powers vary proportionably. The gradua conduction of heat through a body may be familiarly illus

ixing pieces of cork with wax to a brass rod, at stances, and applying heat to one end of the rod; of cork will fall off in succession. Dense and odies are generally good conductors, while those light and porous conduct heat imperfectly. f this difference are of daily occurrence: metallic s which are required to be held in the hand, re furnished with wooden handles, metals being uctors, and wood an imperfect one. A needle, ne extremity in the flame of a candle, becomes nediately so much heated as to burn the fingers; n of a glass rod of equal length may be held in ntil it melts, the other end being little affected. f writing paper be rolled round a smooth brass laced over a gas burner, the heat is conducted apidly by the metal, that the paper is not even d; if the paper be rolled round a cylinder of similarly exposed to heat, it becomes discoloured, he feebler conducting power of the wood; but, if e rolled round a piece of charcoal, and exposed ne heat, it immediately ignites. In particular ever, there is no relation between the density of their conducting power: platinum, for instance, st dense of the metals, and yet it is one of the ductors among them; and glass is a worse con- n many substances of less than half its density. tals, silver is stated by Ingenhousz to be the best ; then copper, gold, tin, iron, and lastly lead. ss, and minerals, come next in conducting power. very imperfect conductors, and, owing to their t detention of heat, they are employed, when l wrapped in cloth, for keeping the feet warm in ter. Still lower in conducting power are ranged porous bodies, as hair, fur, wool, &c.; charcoal is worst conductors. In proportion as the particles

acting

are separated from

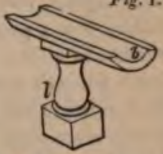
minishes: thus, the

inferior conducting powers to those of the metals the selves. Sawdust conducts heat more feebly than wo *Snow* is an imperfect conductor of heat, and is therefor great use in protecting vegetation from frosts and sev cold; if snow falls early in the season, and remains lo a good crop of grain may be expected; in the absence snow, the crop is often said to be 'winter-killed.' So gr is the protecting power of snow, that in Siberia, where air is 70 degrees below the freezing point, the temperat of the earth is stated to be seldom colder than that of freezing point itself. *Sand* is a very imperfect conducto 'The red-hot balls, employed by the garrison at Gibraltar destroy the Spanish floating batteries, were carried from furnaces to the bastions in *wooden* barrows, with only a la of sand interposed; and this was found sufficient to preve the balls, though in a high state of incandescence, fro setting fire to the wood.'—It is upon the principle of im perfect conduction that certain substances are selected articles of *Clothing*. The object of clothing is, in co weather, to prevent the escape, or conduction, of heat *fr* the body; and, in warm weather, to prevent the too rap communication, or conduction, of heat *to* the body. Hen animals are clothed in fur, wool, down, and feathers; a man in great measure borrows his clothing from the *Flannel* is a bad conductor; hence, the Fire King cloth himself in flannel, previously to entering the hot oven; an hence, ice may be preserved from melting, during summ by being wrapped in the same material. It has been served that the finer the texture of woollen cloth is, more imperfectly does it conduct heat; and that the anim of cold climates are furnished with finer and softer wool fur than those of warmer countries. The comparative c ducting powers of various articles of clothing are exhibi in the following table by Count Rumford. A thermome in the open air occupied 576 seconds in cooling down 13 but when surrounded by the following substances, it oc pied the periods of time annexed to each, the worst c being that in which it occupied the longest time in :—

	No. of seconds.		No. of seconds.
silk . .	917	Raw silk . .	1284
lint . .	,1032	Beaver's fur .	1296
on wool .	1046	Eider down . .	1305
p's wool .	1118	Hare's fur . .	1315

ry interesting phenomenon connected with the com- tion of heat between metals, was discovered by Mr. an. In many cases in which metals at different atures are brought into contact, larly when a heated curved bar s *b*, is made to rest upon a cold r of lead *l*, the hot metal is into a state of vibration, accom- by the production of a musical This effect appears to depend repulsive power existing between the heated sur- which is increased in this case by the low conducting of the lead, the surface of which admits of being y heated by the brass. Professor Forbes observes e most powerful vibrations are produced between the nductors and the worst conductors of heat, the latter he cold bodies.

Fig. 1.



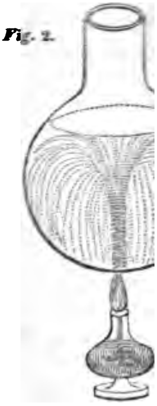
following table presents the different conducting of several solids :—

	Conducting power.		Conducting power.
. . . .	1000	Tin	303
r	973	Lead	179.6
er . . .	898	Marble	23.6
num . . .	381	Porcelain . . .	14.2
. . . .	374.3	Clay	11.4
. . . .	363		

old 1000

12. *Liquid bodies* are very imperfect conductors If heat be applied to the surface of a liquid in a v when ether is poured on the surface of water and i the heat passes downwards so slowly, as to have doubt whether it is conducted at all by the liquid, rather by the sides of the vessel. Dr. Murray, h contrived to make a vessel of ice, and filled it with temperature of 32°; a thermometer was fixed some neath the surface of the liquid. On applying hea surface, the thermometer rose 5½° in 7 minutes, viz. this small amount of heat must have passed through for the walls of the vessel would have been melted b most liquids, however, the power of conducting h feeble, that a portion of liquid may be boiled off f surface in a long tube, while the temperature at a l tance beneath the surface is scarcely affected.—Bu be applied to the lower part of a vessel containing w whole mass soon becomes hot, and we might henc to conclude that the liquid is a good conductor of h explanation of the fact is this:—The heat being a the liquid, the heated portions expand, become ligl ascend rapidly through the liquid; these portions are replaced by others, which are successively heated, and pass upward; thus, ascending and descending currents are established, as shown in this figure, until the whole mass is heated. The diffusion of the heat depends, therefore, upon the motion produced among the several parts of the liquid. It is an act of *Conveyance*, and not of conduction from particle to particle. The motions produced by heat in the above experiment may be clearly shown by placing some

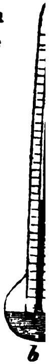
Fig. 2.



coloured and insoluble powder in the flask of water: the coloured matter will continue to ascend and descend, until becomes entirely diffused throughout the liquid. Similar effects are produced on applying cold to the surface of a liquid: the cooled portions become heavier, descend, and force up the warmer and lighter portions, until an equilibrium of temperature is established.—Liquids, like solids, appear to conduct, or *convey*, better in proportion as they are more dense. Thus, spirit of wine, a very light liquid, is a bad conveyor; oil is heavier, and conveys better; proof spirit is still heavier, and conveys proportionably better; water is heavier than any of the preceding liquids, and exceeds them all in its conveying power; and mercury, the heaviest of all liquids, is comparatively a good conveyor of heat.

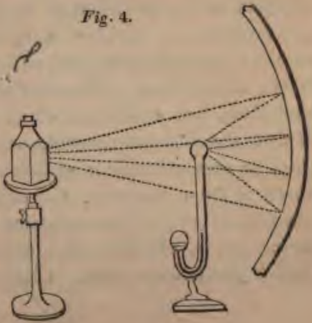
14. *Aeriform bodies*, as gases and vapours, are also very imperfect conductors of heat. Metals are painful to the touch, when heated to 120°; water is capable of scalding at 150°; but the human body may be exposed to air at a temperature of nearly 300°, without having its heat increased beyond two or three degrees. Workmen are in the habit of entering ovens, in manufactories of moulds of plaister of Paris, in which the thermometer is almost 100° above the temperature of boiling water, and of remaining in them for several minutes at a time. In such an atmosphere, the contact of a good conductor would cause pain, as was experienced by a gentleman who entered the oven with his silver-mounted spectacles on; his nose was burned. Sir Joseph Banks and Sir Charles Blagden were able to endure the heat of a room at the temperature of 264°, or 52° above that of boiling water; but they found that their hands could not endure the heat of their watch-chains or metallic buttons.—The usual mode of diffusion of heat among aeriform bodies appears to be, as in liquids, by an act of *Conveyance:* the heated portions ascend, carrying the heat with them. Hence, in heating apartments by hot air, the flues are placed in the floors or lowest part.—Upon the same principle *may be explained* the phenomena of Winds, which

the amount of moisture in the air. -
hygrometer is constructed upon this pri
ally used at present. This instrument consists of two balls, connected together by a tube bent in the form of a siphon, as represented in the figure. The ball *b* contains some ether, from which the air has been expelled in the same manner as in the cryophorus. A thermometer is placed in this arm of the siphon tube, and its bulb descends into the ball. A zone of the ball is gilded and burnished, in order that the dew deposited upon it may be visible. The other ball *a* is covered with muslin, which is kept moist by constantly dropping ether upon it. The evaporation of the ether from the ball *a* condenses the vapour from the ball *b*, the temperature of which is gradually reduced till dew is deposited
upon the burnished part of the ball. Th
the deposition takes place is indicated by
mometer; this degree is called the *de*
temperature of the ball *b* is allowed to ri
ance of the dew takes place at about the
mean point between its appearance and
strictly indicate the dew point. The ther
to the stem of the instrument is for ind
perature of the atmosphere at the time of
Leslie's hygrometer consists of the differen
having one of the balls covered with musl
be easily moistened; the less moisture th
the more rapid is the evaporation from the
greater the reduction of temperature. T
Snow, Sleet, Hail, and Rain, are owing to



ct at the distance of one foot be reckoned as 1, at two feet ill be as 1-4th, at three feet as 1-9th, at four feet as 1-16th, so on.—Different bodies vary in their power of radiation, therefore do not cool, after having been heated, with al rapidity. Leslie found that the rapidity with which ies cool, depends more upon the condition of their *sur-* e, than upon the nature of their *substance;* and that gh and porous bodies radiate very powerfully, while shed metallic surfaces radiate very feebly. He filled a ght tin vessel with hot water, and having placed a ther- meter in it, found that the temperature of the water fell way to that of the apartment in 156 minutes; but, on ering the vessel with a thin coating of lamp-black, the perature fell to an equal extent in 81 minutes, or about the time it required with the bright surface. If the sel be wrapped in linen, or coated with white or black nt, the cooling is similarly accelerated. A simple ex- iment may be performed with merely two thermometers, one having its bulb coated with lamp-black, the other ng clean; on raising them both to the same temperature exposure to a fire, and allowing them to cool, the mercury the blackened one falls much more rapidly than that in e other. In determining the radiating power of different rfaces, Leslie used square tin canisters, the surfaces of iich were coated with different substances, and which were led with hot water. he surfaces were pre- nted, successively, to a etallic mirror, having e bulb of a differen- al thermometer (p. 39) aced in its focus, as own in the annexed ure. In these experi- ents, a surface covered ith lamp-black caused rise of temperature

Fig. 4.



equal to 100; a papered surface, 98; a glass surface, and a metallic surface only 12. In heating apartment steam or hot water, the surfaces of the tubes are blacke in order that the heat may be diffused more rapidly.

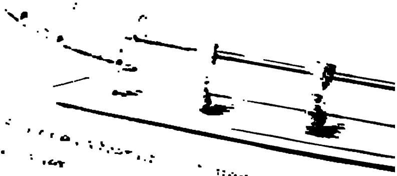
The following table exhibits the different radiating p of various substances :—

	Radiating power.		Radiating p
Lamp-black	100	Tarnished lead . .	
Writing paper . . .	98	Clean lead . . .	
Sealing wax	95	Polished iron . .	
Crown glass	90	Tin plate, gold, silver, copper	
Plumbago	75		

16. The *Deposition of Dew* has been shown by Dr. to depend upon the cold produced by the radiation c from the surface of the earth. When the direct influ the sun is withdrawn, the surface of the earth rad portion of its heat into the surrounding space; and th air immediately in contact with it becomes cooled, a watery vapour, which is always present in it, is con and deposited in the form of dew. The difference b the radiating powers of different surfaces produces sponding effects on the deposition of dew: one portion earth's surface, or one portion of herbage, may be with dew, while another portion in the immediate bourhood is perfectly dry. That the deposition depends on the radiation of heat is shown by the fol circumstances. 1. Dew is always most abundant calm and cloudless nights, and in situations freely e to the atmosphere. Whatever interferes with the pro radiation, has a decided effect on the deposition o Hence, the slightest covering or shelter, as that of thi ting, or even muslin, is sufficient to protect the obje neath it from the cold, the effect of radiation, and quently, to prevent the formation of dew,—a fact well to gardeners, of which they avail themselves in pro tender plants from frost. Similar effects are produ

ters interposed at a great distance from the earth's sur- : clouds effectually prevent the radiation of heat from earth's surface, so that cloudy nights are always warmer those which are clear, and there is, consequently, on nights, little or no deposition of dew. 2. Dr. Wells shown that the quantity of dew which is deposited on rent substances, under similar circumstances, is pro– ional to the radiating power of their surfaces. On ex- ng a plate of metal and a quantity of wool together, a e quantity of dew is condensed on the wool, while cely a trace of dew is found on the metal; wool, being better radiator, falls to a lower temperature than the al.—From dew there is an insensible transition to *Hoar st*, which is in fact only frozen dew, and indicative of ter cold. It is found, therefore, that frosty nights, like ply dewy nights, are calm and clear. On a calm night, temperature of a grass plot is frequently 10° or 15° lower that of the air at a few feet above it. Hence, in our ate, vegetables are liable to be exposed at night during months of the year to a freezing temperature; and even uly and August to a temperature only 2° or 3° warmer. hence it is that trees of lofty growth frequently escape g injured by frost, while plants nearer the ground are e destroyed.

7. *Arnott's Stove.*—Dr. Arnott's *Self-regulating Fire, hermometer-Stove*, is constructed upon the principle of ng out its heat 'partly by radiation all around it, but fly by warming the air which touches it. This air then nds, and spreads over the ceiling, warming that, and soon ownward radiation from the ceiling, and farther motion mixing of the air, from the descending currents pro- d, because the walls absorb the heat of the air which hes them, the whole room is more or less equally warmed.' following figure represents a box formed of sheet-iron, aining a fire-box or furnace, formed of iron, and resting close ash-pit, which communicates with the external air. is cut exhibits, perhaps, the simplest form of the ex-



[illegible] movem[illegible] [illegible]able [illegible] tion. [illegible] transvers[illegible] lateral [illegible] increases [illegible] distance

The fracturing of glass vessels on pouring hot them is owing to the expansion of one surface, heat is conducted to the other: hence it is the thinner the glass is, the more secure it is against and that the best mode of avoiding fractures is glass vessel very gradually. *Plate* glass is always [illegible] being fractured by heat.

The following table exhibits the *different* [illegible] in several solid bodies. On heating [illegible] from the freezing to the boiling poi they become longer in the following proportions

Lead	gains	1	part in		35i
Silver	.	1	—	.	52
Copper	.	1	—	.	5
Brass	.	1	—	.	5
Gold	.	1	—	.	6
Iron wire		1	—	.	81
Platinum		1	—	.	116
Flint glass	.	1	—	.	124

[illegible] expand much more than expansion of a liquid may be seen on applying the bulb of a common thermometer: the liqu bulb by the warmth and rises in the tube. L in different degrees, those being the most exp require the least heat to make them boil. Th pands more than mercury, spirits of wine mor ether more than spirits of wine. On being he freezing to the boiling point of water, alcohol of its volume, oil of turpentine 1-14th, wa mercury 1-[illegible]. The different expansive liquids may be readily seen on immersing tw with tubes attached to them, the one contai other alcohol, in equal quantities, into a vesse the alcohol will be found to rise in the tube high as the water.—Water, at a certain ra tures, exhibits a remarkable *exception* to the

the

from an

below the

his scale.

On

scending degrees The

and

which was calculated to require, for this purpose, a
from within equal to 27,720 pounds. Several m
pand, as they pass to the solid form after fusion,
therefore employed for casting in moulds, owing
power of insinuating themselves into all the minute
and so forming a perfect impression of the mo
liquids, as in solids, the expansion increases in gr
grees than are proportionate to the elevation of tem
If mercury, on being heated from 32° to 122°, or 90
expands 14 times, then on heating it to 212°, or 90
more, it expands 15 times more. The expansion
from 32° to 122° is 4·7 ; from 122° to 212°, it is 15

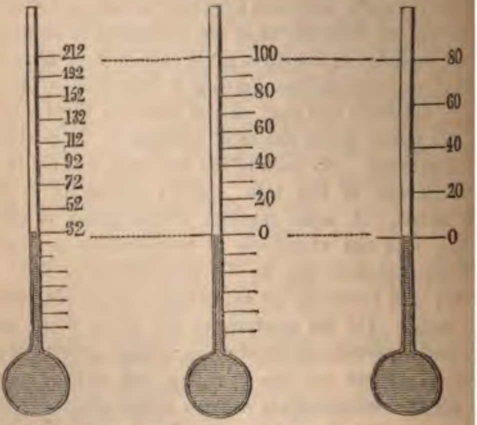
26. *Aëriform bodies* expand much more by h
liquids, the particles being in less intimate union,
under the influence of cohesive attraction. The e
of air is 8 times greater than that of water ; that
45 times greater than that of iron. If a bladder pa
with air be held for some time to the fire, it will appear full; and on cooling, it will shrink to its original bulk. If the neck of a flask, containing some water, be inverted into a bason of water, and the flame of a lamp applied to the large part of the flask, or even the hand applied closely over this part, the water will be forced out by the expansion of the air within; on removing the source of heat, the water will return into the flask.—All aëriform bodies, if perfectly free from
watery vapour, expand *equally* on the application
degrees of heat ; the rate of expansion is 1-480t
their whole bulk for every degree of Fahrenhei
mometer. It has been found that 100 parts of a
expand to 137.5 parts, when heated to 212° ; th
temperature being raised 180°, the increase in bul
which is nearly 1-480th part for each degree.

[illegible]

[illegible]

employed in France; it consists in an arrangement of scale, in which the freezing point is marked 0, or *zero*, the boiling point 100°. In *Reaumur's* thermometer, wh is employed in the north of Germany, the freezing poin marked 0, or *zero*, and the boiling point 80°. The deg are continued of the same size below and above these poi those below being reckoned negative. A figure is ad showing the correspondence of the three thermometers.

Fig. 11.



These different modes of graduation are easily co tible: the Centigrade scale is easily reduced to th Fahrenheit by multiplying by 9, and dividing by 5; tl Reaumur to that of Fahrenheit by dividing by 4 in of 5; or that of Fahrenheit to either of the others, b versing the process. Thus:—

Cent. 100° × 9 = 900 ÷ 5 = 180 + 32 = 212° Fal
Reaum. 80° × 9 = 720 ÷ 4 = 180 + 32 = 212° Fal

Or, by reversing the order:—

Fahr. 212° − 32 = 180 × 5 = 900 ÷ 9 = 100° Cen
Fahr. 212° − 32 = 180 × 4 = 720 ÷ 9 = 80° Reaur

Sanctorius invented the *Air Thermometer*, the principle which may be understood from Fig. 10. This instrument, ugh more delicate in its indications than those in which rcury or alcohol is used, is affected by the pressure of the osphere, independently of temperature, and is therefore dom used. The *Differential Thermometer* consists of o glass bulbs, connected by a glass e bent in the form of the letter U. e tube is partly filled with a co- red liquid. On exposing one bulb heat, the expansion of the air ces the liquid down, and causes it rise in the opposite part of the e. This instrument is not in- ded to indicate the temperature the atmosphere, as the application cold or heat to both bulbs at the ne time produces no alteration in e level of the liquid; it merely in- cates the *difference* of temperature between the two bulbs.

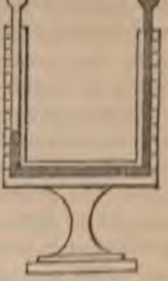


Fig. 12.

Rutherford's Register Thermometer*, the highest and

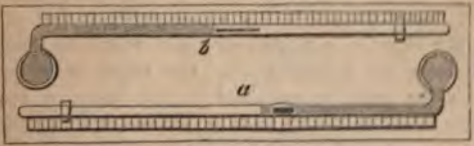


Fig. 13.

west temperatures which occur within a given time are dicated and made to register themselves. This instrument onsists of two thermometers, placed with their tubes in a orizontal position, as shown in the figure. The one *a* ontains spirit of wine, the other *b* contains mercury. In e stem of the thermometer *b* a small iron wire, placed at e surface of the mercury, acts the part of an index, being ropelled forward as the mercury expands, and being left at

their *capacity* for heat; and the quantity of h
by each body in order to raise it to a certain tem
called its *specific heat.* It has been found, by
that a pound of water absorbs thirty times more
pound of mercury, in being raised to the same te
in other words, the capacity of water for heat is th
greater than that of mercury. The following are
heats of a few substances:—water, 1000; sulp
glass, 117; iron, 110; copper, 95; silver, 56;
lead, 29.—The capacity for heat which bodies p
creases in greater proportion than the temperature
they are raised: the capacity of iron, for instance,
32° and 212° is 110; but between 32° and 392°,
and, between 32° and 662°, it is 126. Of all bodies
liquid, water has the greatest capacity for heat.
capacity of *steam* for heat is less than that of
weight of water, being only 847; hence we learn,
specific heat of a body varies with its physical sta

44. The *capacity of bodies for heat* appears to be,
in inverse ratio to their specific gravities. The
of water to mercury is as 29 to 1, its specific gra
1 to 14. The capacity of hydrogen is 12 times gre
that of an equal bulk of atmospheric air, though
about 13 times heavier than the gas. Hydrogen, th
of all bodies, has the greatest capacity for heat;
metals, the heaviest of all bodies, have the leas
any substance undergoes *increase in bulk*, its
diminished, and its capacity for heat increased. I
thrown upon the bulb of a thermometer, it assume
of vapour; its bulk being thus increased, its ca
t is also increased, and it derives heat from the
falls. When aëriform bodies a
exhausted receiver of an
or as they escape from
one pressure, they exp
to , and their temperature
The w form bodies are compre

r heat is diminished, heat is liberated, and the re rise. Hence a change of capacity, without the quantity of communicated heat, is accom a change of temperature.—That bodies contain [illegible] of *latent* heat is proved by the following. It has been already noticed that a piece of [illegible] be hammered till it becomes red hot: this effect the evolution of heat, which, while latent, only gave the iron malleability and ductility, but when rated, operates with as much activity as if it had [illegible] latent. [illegible] nitric sulphuric acid be mixed [illegible] an ounce of nitric acid, and the mixture be poured turpentine, the whole will burst into flame. [illegible] the *compound* having less capacity for heat than ents separated, consequently a portion of the erated and produces inflammation. [illegible] an apparatus for ascertaining the specific [illegible] bodies, by means of which a [illegible] carried a coil current of another [illegible] [illegible] in which a thermometer [illegible] [illegible] of each gas we ascertain [illegible] heat. Thus [illegible] knowing [illegible] after they [illegible] determine

[illegible]

[illegible]

Heat communicated ?— [illegible]

? heat ? What [illegible]

? Explain th [illegible]

stances are selected for clothing. Explain the manner in which heat is conducted through Liquids. Give an instance of the conducting power of Air.—15. What is meant by Radiation of heat? Upon what circumstance do the different radiating powers of bodies depend?—16. Upon what circumstances does the Deposition of Dew depend?—17. Explain the principle of Arnott's Stove.—18. In what way is heat distributed?—19. What relation has Reflexion of heat to Radiation?—20. What relation has Absorption of heat to Radiation?—21. How is heat affected towards bodies which neither absorb nor reflect it?—22. Explain the deceptive effects which heat produces upon the *senses*.—23. How is the *bulk* of bodies affected by heat?—24. State some useful applications of expansion by heat, in the arts. Explain the principle of the *Compensation Pendulum*.—25. How does water exhibit a remarkable *exception* to the laws of Expansion and Contraction?—26. State the comparative expansibility of bodies in the three states of solid, liquid, and aëriform.—27. What is the Thermometer? Explain the principle of Fahrenheit's thermometer; and of the Differential thermometer.—28. How may a change in density be proved to be a result of change in temperature?—29. How is the *form* of bodies affected by heat?—30. What is *latent* Heat? Explain the principle of *freezing mixtures*.—32. Give some instances of Evaporation at common temperatures. Describe the *Cryophorus*.—33. What are the circumstances which influence evaporation? What is the *hygrometer*?—34. What is Ebullition?—37. How is the boiling point of liquids affected by Atmospheric Pressure?—40. What is *high-pressure* steam?—41. What is meant by the Diffusion of Gases?—42. What is Incandescence?—43. What is Specific Heat?

CHAPTER II.

OF LIGHT.

. *General Remarks.*—Light is the agent by which es are rendered perceptible to the sight. Its nature has ys been involved in considerable mystery. According ewton, light has a material existence, and consists of ute particles of a very subtil nature, which emanate luminous bodies in right lines with inconceivable ve- y. According to more recent writers, light has no erial existence, but its effects are produced by vibrations ndulations of a subtil ethereal medium universally dif- d through nature; according to this theory, the phe- ena of light are produced by pulsations of ether on the na of the eye, as those of sound are by pulsations of air on nerve of hearing. Light is of two kinds; natural and ficial. The Sources of *Natural Light* are the Sun and rs; those of *Artificial Light* are Electricity, Mechanical tion, and Chemical Action. The laws which preside r the phenomena of light belong to the science of Optics. ey will, therefore, be pointed out here very briefly. Our ef object must be to trace their connexion with the phe- mena of Chemistry. It will be observed that they bear marked relation to those of heat and electricity. They y be conveniently studied under the heads of—

1. *Radiation of Light.*
2. *Reflexion and Refraction of Light.*
3. *Polarization of Light.*
4. *Decomposition of Light.*
5. *Phosphorescence.*

46. *Radiation of Light.*—Light moves, like heat, by radiation in straight lines in all directions from luminous bodies. The velocity of its motion is so great that it occupies scarcely eight minutes in passing from the sun to the earth; it consequently moves at the rate of nearly 200,000 miles in a second, and would occupy only 1-8th of a second in traversing a space equal to the circumference of our globe. The intensity of light increases and diminishes inversely as the squares of the distance between the luminous and the illuminated body. This may be illustrated by a simple experiment. If a board a foot square A B be placed at the distance of one foot from a candle G, it will hide the light from a second board of two feet square C D, placed at the distance of two feet from the candle; or, of a board three feet square E F, placed at the distance of three feet from the candle. Now, a board of two feet square is *four* times as large as a board of one foot square; and a board of three feet square is *nine* times as large as that of one foot square; thus, the light, at double the distance, is spread over four times the surface, and at treble the distance over nine times the surface, it was spread over at the first distance. As the divergence *increases*, the intensity *decreases*. The application of this principle to the diminution of light which we should suffer on being removed further from the sun's influence, is obvious.

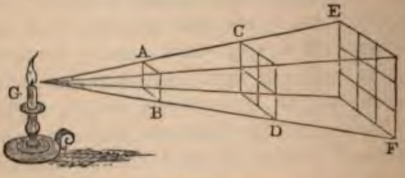


Fig. 19.

47. *Reflexion and Refraction of Light.*—The preceding remarks apply to the rays of light, as they move in free space. But when a ray falls upon a polished surface, as

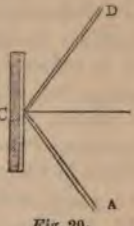


Fig. 20.

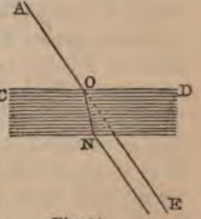


Fig. 21.

glass C, in the direction A C, a portion of it may be *re-*
cted from that surface, and bound off
the opposite direction C D; in this
se, the angle formed by the *incident*
y A C, is always equal to that formed
the *reflected* ray C D. When light
reflected from a body, the body be-
mes visible, and is seen in the direc-
n in which the rays reach the eye.—
ut another portion of the ray, instead
being reflected, may pass obliquely
rough the glass. In this case, instead
passing through the new medium C D, in its natural di-
ction of a straight line A E, it will be
nt on entering the glass, from O to N,
d, on making its exit at N, it will be
ain bent in the contrary direction,
d proceed onwards in a straight line,
rallel to its original course. This
rtion of the ray is said to be *refracted;*
other words, its direction has been
oken. It may be stated as a *law,*
at, when light passes obliquely into a
nser medium, it is refracted *towards*
e perpendicular; and, on its emergence into a rarer me-
um, it is refracted *from* the perpendicular. The amount
the refraction is, generally, proportionate to the density of
e body; but combustible bodies exhibit a greater refracting
wer than accords with their densities.—Some crystallized
dies, as Iceland spar, present the phenomenon of *double*
fraction, one portion of the light being refracted in the
dinary way, while another portion undergoes *extraordinary*
fraction "in a plane parallel to the diagonal which joins
e two obtuse angles of the crystal." Hence, such sub-
nces present a *double image* of any body which is viewed
rough them. This property of double refraction occurs in
any minerals and artificial salts, and may be communi-

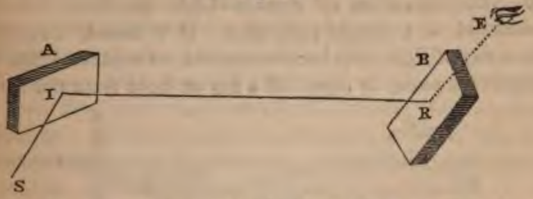
cated temporarily or permanently to substances in which it does not naturally reside.—In passing through most transparent bodies, much light is lost by *absorption* and by irregular reflexion. In falling upon metallic bodies, about one half only is reflected, the other half being absorbed or lost. It appears, from experiments, that in fluids, transparent solids, and metals, the quantity of light reflected *increases* with the angle of incidence, reckoned from the perpendicular, whereas in white opaque bodies, the quantity *decreases* with the angle of incidence.

48. *Polarization of Light.*—When a ray of light has been *reflected* from the *surface*, or *transmitted* through the *substance*, of any homogeneous uncrystallized body, the property of the reflected or transmitted light continues the same, so long as the light falls on the first surface always at the same angle; that is, the different *sides* of the rays exhibit no difference of property, in relation to the plane of its incidence. Such light is called *common light.* But when the body, from which the ray is reflected, or through which it is transmitted, is turned round so that the light falls upon it at one particular angle, the properties of the reflected or transmitted light are *changed;* it has acquired the property of entering transparent bodies at certain angles, and not at any others. Hence it follows, that the different *sides* of such rays have different properties in relation to the plane of their incidence. Such light is termed *polarized light*, in consequence of its rays having *poles*, or sides with different properties, like those of a magnetic bar. Polarized light may be procured in three ways:—1, by *reflexion* from the surfaces of transparent and opaque bodies;—2, by *transmission* through a number of plates or planes of uncrystallized bodies;—and, 3, by transmission through bodies regularly crystallized, and possessing the property of double refraction.

49. One of the properties of *polarized light* consists in its *not* being reflected, like common light, when it falls upon a second reflector. In the following figure, S I is a ray of light

falling upon the vertical glass A, at an angle of incidence of 56°; it is then reflected in the direction I R upon the glass B at the same angle of incidence of 56°; and from this second glass it is reflected to E, where the eye is placed to receive it. In this apparatus, in which the *first* reflexion is in a *horizontal* plane S I R, the *second* in a *vertical* plane I R E, the ray R E will be so weak as to be scarcely visible, having almost entirely passed through the glass B, or become extinguished. But if the glass B be turned round (the ray I R being the axis of motion), the ray R E will become more and more vivid, till the glass plate has been turned round 90°; at this point the plane of reflexion I R E will be horizontal, like that of S I R, and at this point the whole of the ray R E will be reflected. On continuing to turn the plate, the ray will become gradually fainter, until, after having turned the plate 90° more, the ray becomes again invisible, the plane I R E being again vertical to the plane S I R. On a further motion of 90°, the ray reassumes its vividness, the two planes being again horizontal; and, on completing the circle, by turning the plate 90° more, it is brought to its first position, and the ray is again invisible. Hence it may be stated as a *law* that, when the plane of the second reflector is *perpendicular* to the first, and the ray falls at an angle of 56°, it is not reflected at all, but *disappears;* but that, when the plane is *parallel*, the ray is entirely reflected. The maximum polarizing angle for glass is, therefore, 56°; that of water, is 52° 45′.

Fig. 22.



50. By the application of *polarized* li
stances, which were formerly supposed to
in their structure, have been found to presen
organization. It has been applied to the i
several mineral, vegetable, and animal structu

51. *Decomposition of Light.*—Light has
considered as a simple substance. It is fou
that a ray of light may be *decomposed*, or sepa
constituent parts, or rays. If a ray of light fr

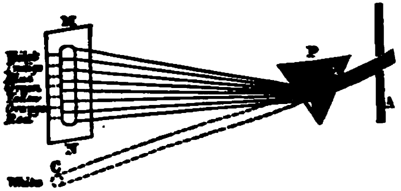


Fig. 22.

be admitted into a dark room through an apertu
window shutter A, and be made to pass through a so
of glass, or *prism*, P, instead of passing onward in i
ral direction C, it is refracted as it enters the glas
again refracted as it passes out of it. If it be now
upon a white card M N, it will be found to have bee
posed, and instead of presenting a round spot of wh
it exhibits an oblong image, consisting of *seven*
different colours, which will be situated in respe
other as named in the figure. This oblong image
the *solar*, or *prismatic spectrum*. When the ray
which have been thus separated, are collected
lens, white or common light is produced. The
of the beams of light composing the spectrum is
their having different refractive powers, the red
fracted in the least, the violet in the greatest deg
their original direction C. Each of the seven col
sists of light which is no longer decomposable, lik
light, but has uniform refractive properties; an

they were termed by Newton, simple or *homogeneous* colours, to distinguish them from common or white light, which he called compound or *heterogeneous*. The coloured bands of the spectrum differ in width, and are shaded into each other; and it has been recently determined by Sir D. Brewster that the *primary* rays of colour are *three* only, blue, yellow, and red, the others being merely compositions of these. A portion of each of the primary rays is found at every point of the spectrum, together with a certain quantity of white light; but each of the primary rays predominates at a particular point of the spectrum. The blue rays are near the top, and are the most refrangible; the yellow are somewhat below the middle, and are less refrangible; the red occupy the lowest part, and are least refrangible. The *compound spectrum* is produced by the combination of the three simple spectra, the blue, the yellow, and the red, which are shaded as represented in the figure. Hence, not one of the seven colours of Newton is pure, the orange being produced by predominance of the yellow and red rays; the green, by the yellow and blue rays; while the indigo and violet are essentially blue, with different proportions of red and yellow. Upon these laws depend the endless variety and change of colours: bodies appear to

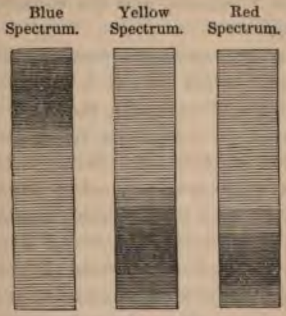


Fig. 24.

have a particular colour, according as they are enabled to reflect or transmit the rays of some colours, and to absorb or reflect the rest; while white bodies reflect all, and black bodies absorb all. Dr. Stark has lately made some important observations on the influence of colour on the absorption and disengagement of *odorous matters.* He found that black clothes absorb much offensive odorous matter, and retain it powerfully, while light-coloured clothes not only absorb it in a trifling degree, but part with what they absorb rapidly on exposure to air. The application of this principle is obviously very important with respect to clothing, white-washing, the retention of noxious effluvia by bodies of different colours, and the consequent communication of disease.

52. The *prismatic spectrum* presents different portions of *heat* at different points. Most heat is found associated with the red rays, and least with the violet rays. Melloni found that transparent substances are *unequally* permeable by luminous and calorific rays: bodies which are almost opaque in regard to light, were found to transmit heat freely, while others of the most perfect transparency are little permeable by heat. To those media which allow a free transmission to heat, he applied the term *diathermanous*, upon the same principle as the term *diaphanous* is applied to those which transmit light. If a prism of some highly diathermanous substance, as rock-salt, be employed, the calorific rays are found to extend, and to have their point of greatest intensity considerably beyond the limit of the visible spectrum, on the side of the red ray. Hence, most of the calorific rays are less refrangible than even the least refrangible of the luminous rays. If a prism of some substance which is feebly diathermanous be employed, as water or crown-glass, the least refrangible rays are absorbed in the greatest proportion; and a spectrum may be thus produced, in which the heat is concentrated in the red ray. The *calorific* rays are distinct from the *luminous* rays, and may be separated from them, owing to the inequality of their refrangible pro-

perties. It was, in fact, discovered by Melloni that light may be divested of *all* heat by being transmitted successively through water, and a glass stained green by the oxide of copper.

53. The *prismatic spectrum* presents also what are called *chemical* rays, capable of producing changes independent of its luminous or calorific rays. Thus chlorine gas, under the influence of light, decomposes water; and a similar effect is produced by the chlorine in recently precipitated chloride of silver; in the former case, the chlorine combines with the hydrogen, and oxygen is set free; in the latter, the oxygen combines with the silver, and changes the colour of the compound from white to black. The chemical effect of light is remarkable in its action upon chlorine and hydrogen, a mixture of which is instantly detonated by bright sunshine. The chemical power is found at the two extremities of the spectrum, particularly at the upper end, where it extends even beyond the limit of the violet ray; these chemical rays are, therefore, more refrangible than any others in the spectrum. The character of the chemical rays is to produce decompositions, in which oxygen is separated from water and other oxides; and hence they are sometimes termed *deoxidizing* rays. Morichini and Mrs. Somerville have stated that the violet rays communicate magnetic properties to iron; but this subject requires further examination.

54. The evolution of *light* by chemical action is exhibited in the phenomena of *Combustion*. These, and the *Incandescence* (p. 58.) of solids and fluids heated to a certain temperature, indicate a connexion between light and heat.

55. *Phosphorescence.*—The evolution of light from various bodies, independently of chemical action, or of the elevation of temperature necessary to incandescence, is termed *Phosphorescence*, and the bodies which exhibit this property are called *Phosphori.*—1. A mixture of calcined oyster-shells and flowers of sulphur, called *Canton's phosphorus*, presents this phenomenon, when exposed to a strong heat. The same property is possessed by chloride of calcium, or

by the movements of the needle on its pivot. Another of these instruments is the electric *pendulum*, which consists of a pith ball, suspended by a piece of silk, or a very delicate metallic thread. On applying an excited body to the ball, it is first attracted, as at A; it is then repelled from it, as at B. If now the ball which has touched the excited body, be brought near another ball which has had no communication with an excited body, they will attract each other, and come into contact; after which, they will repel each other, as will be presently described.

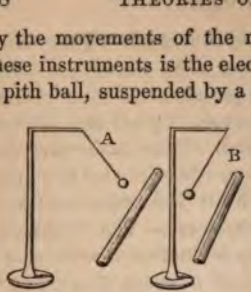


Fig. 26.

61. *Theories of Electricity.*—There are two theories for explaining the phenomena of Electricity.—1. According to the views of Franklin, they depend upon a *single fluid*, its effects being produced by its being accumulated, or rendered deficient, in different bodies; when it is accumulated in excess in a body, its effects are produced by its being communicated to surrounding bodies; when it is deficient, the effects occur from the communication of it from surrounding bodies to that in which it is deficient; until, in each case, the *equilibrium* is restored.—2. It is supposed by others that there are *two fluids* of a different nature, and that different bodies possess different kinds of electricity. It has been observed that bodies which have been electrified by excited *glass*, repel one another, and are likewise repelled by the excited glass. Similar results occur when the bodies have been electrified by excited *sealing-wax*. But it is found that when one ball has been electrified by glass, and another by sealing-wax, these balls, instead of repelling, attract each other; and, in bringing these balls, charged in an equal degree, into contact with each other, they cease to exhibit any signs of electricity, as if the electric *equilibrium* had been immediately restored. It appears, therefore, that the electricities of glass and of sealing-wax are not identical, since each *attracts* that which the other *repels*. The former

portional to its heating effect when absorbed. It consists of his differential thermometer, (p. 39.) having one of its balls blackened. The clear ball transmits all the light it receives, and its temperature is therefore not affected; whereas the black ball absorbs all it receives, and, by expansion of the liquid, produces a corresponding *ascent* of it in the opposite stem. The whole instrument is covered with a case of thin glass, to prevent the balls being affected by currents of air. When light produced by combustion, or by common bodies in a state of incandescence, is employed, the indications of this photometer are inaccurate. The *calorific* effect of red-hot coke, for instance, is more powerful than that of many kinds of light, which are much more powerfully *luminous*.

RECAPITULATION.

45. What are the principal phenomena of light?—46. In what way does light move, and with what velocity? At what rate does its intensity increase and diminish?—47. When a ray of light falls on the surface of a body, what are the two courses which it may follow? What relation does the angle of *incidence* bear to that of *reflexion?* What circumstances produce refraction of a ray of light?—48. Explain the *new* property acquired by reflected or refracted light.—49. State the *law* which regulates the polarization of light.—51. How may a ray of light be decomposed? What is the *prismatic spectrum?* What are the primary colours, and how are the other colours produced? State the relative refrangibility of the different colours.—52. At what part of the spectrum are the *calorific* rays chiefly found? How are they shown to be distinct from the *luminous* rays?—53. Where are the *chemical* rays found? State some of the chemical effects of these rays.—55. What is Phosphorescence? In what substances does it reside?—56. Explain the principle of Leslie's *photometer*.

rubbed with the same substance; sealing-wax is rendered positive by metallic substances, but negative by hare's skin. All bodies capable of being excited, are called *electrics;* the principal of these are amber, gum-lac, resin, sulphur, glass, talc, the precious stones, silk, the fur of quadrupeds, and almost all vegetable substances (excepting charcoal) which have been thoroughly deprived of moisture, as baked wood and perfectly dry paper. Every one is familiar with the crackling sparks which are produced by stroking the back of a cat.—After a certain time, which varies in different substances, the attracted body is *repelled* from the electric; and, on again presenting to it the electric, it is again repelled, provided it has touched no other body in the meantime. It is also found that two bodies, which have been in contact with the same electric, mutually repel each other.—When it is required to procure a large quantity of electricity for purposes of experiment, an *electrical machine* is employed. This consists of a large electric made of glass, either in the form of a cylinder, or of a flat circular plate; and of a rubber or cushion of leather stuffed with horse-hair. The subjoined figure represents such a machine. A is the electric, mounted on an axis and furnished with a handle; R the rubber fixed

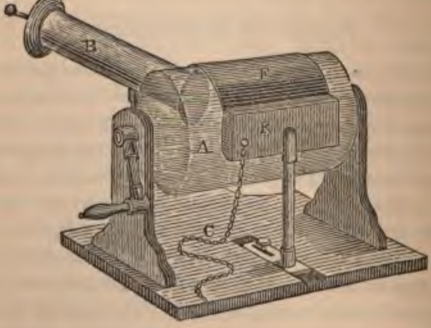


Fig. 27.

67. *Excitation by Induction.*—Electricity is exhibited by bringing an unelectrified body into the neighbourhood of an electrified body; such electricity is said to be *induced*, or excited by *induction*. From what has been already said of the mutual attraction and repulsion of the two electricities, it will readily be inferred that an excited body tends to induce in an unexcited body an electrical state opposite to its own. The electricity, for instance, of a positive body repels the corresponding electricity of a neighbouring body to its further extremity, and attracts the opposite electricity to its near extremity. This phenomenon is illustrated by the annexed figure. A B is an unexcited conductor, supported on an insulating glass leg *b c*, while C is a body containing positive electricity, similarly insulated, and placed near the conductor. The positive electricity of C repels the corresponding electricity of A B to its further extremity, and induces the opposite electricity to its near extremity. The relative position of the two fluids is indicated by the signs + and −, the former denoting the *positive*, the latter the *negative*, electricity. On removing the body C, the equilibrium of the body A B is restored, neither of the bodies having gained or lost any thing by the experiment. If, on the other hand, the repelled electricity of A B be neutralized by communication with the ground, and if during the induction the connexion be broken, this body is left with an excess of negative electricity.

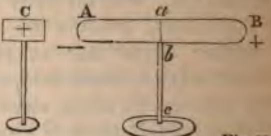


Fig. 28.

68. The action of the *Leyden Jar* depends on the principle of *induced Electricity*. It is a contrivance by which electricity can be accumulated in larger quantity than in the prime conductor. A glass jar with a wide mouth is coated both internally and externally with tin-foil to within a third of the top, the upper part being left naked to prevent a spon-

Fig. 29.

taneous discharge, or the passage of the electric fluid from one coating to the other. The aperture is closed by a disc of dry wood, through which is passed a metallic rod, communicating with the inner coating, and terminating externally in a brass knob. On placing the knob in contact with the prime conductor of an excited electrical machine, while the outer coating communicates with the ground, the interior of the jar becomes positively, the exterior negatively, electrified. If the jar be insulated, and the knob be placed near the prime conductor, without actual contact with it, while an uninsulated conductor is placed at an equal distance from the outer coating, electric sparks of equal size and number will pass between the two intervals, and the interior and exterior of the jar will maintain the same condition as they had before; but no charge will be received, if, when the inner coating communicates with the prime conductor, the outer coating be strictly insulated. From these facts it is concluded that the interior of the jar becomes positive by communicating negative electricity to the prime conductor; and that the exterior then becomes negative by the loss of a quantity of positive electricity equal to that on the interior.—By connecting together a sufficient number of Leyden jars, a large quantity of the electric fluid may be accumulated. For this purpose, all the interior coatings are made to communicate with each other by metallic rods, which finally terminate in a single knob; communication is also established between their outer coatings by placing them in a box lined with tinfoil; the whole series may then be charged as if they formed but one jar; and they may all be discharged at the same moment. Such an arrangement is called an *Electrical Battery.*—When it is desired to discharge a jar, or a battery, a communication between the two surfaces is effected by means of a *discharging rod.* This instrument consists of two bent metallic rods, each of them terminating at one end in a brass knob, and connected at the other end by a joint, which is fixed to a glass handle. The brass rods being opened to a

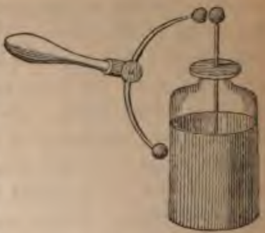


Fig. 30.

proper distance, the knob of one is brought in contact with the outer coating of the jar, while that of the other is applied to the knob of the jar; the discharge is thus effected, and the equilibrium restored between the interior and exterior surfaces of the jar. When it is desired to pass the electric fluid, thus obtained, through any substance, this must be placed between two metallic conductors, the one communicating with the outer, the other with the inner coating of the jar, or battery.

GALVANISM, OR VOLTAIC ELECTRICITY.

69. The effect of Electricity upon animals was first noticed by Galvani. He found that when two metals, as zinc and silver, the one in contact with the crural nerve of a recently killed frog, the other with the muscles to which the nerve is distributed, are brought into contact with each other, muscular contraction ensued. This fact gave rise to the science called *Animal Electricity*, or *Galvanism*. This phenomenon was attributed by Volta to the disturbance of the electric equilibrium by the contact of two dissimilar metals. The identity of the common and the Galvanic electricities was proved by the discovery of the Voltaic pile, and the science has from that period been termed by some writers, *Voltaism*, or *Voltaic Electricity*.—If a plate of zinc and a plate of copper be immersed to a certain depth in a vessel containing dilute sulphuric acid, and connected together by direct contact, as in this figure, a

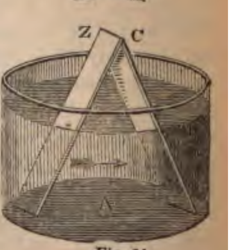


Fig. 31.

onsidered that electricity is developed in the
by metallic contact, and that it is afterwards
chemical action. 'The progress of inquiry,'
rner, 'since these theories first came into
adually given more and more support to the
llaston, and has at last, I apprehend, esta-
to the entire exclusion of the theory of Volta.
damental position, that electricity is excitable
result by the contact of different substances, is
tested, and, as some think with strong reason,
proved; but admitting, for the sake of argu-
a *small* effect, which is all that can now be
or, may thus be produced, it is altogether in-
when contrasted with the astonishing pheno-
ted by a Voltaic circle.'*

EFFECTS OF ELECTRICITY.

hanical Effects of Electricity.—The mechanical
lectricity have been already described; they are
those of Attraction and Repulsion. When ac-
in sufficient quantity, and retarded in its course
luctors, it operates in the same powerful manner
htning is arrested in its progress to the earth, by
ontact with a building. It is necessary, in this
int out the distinction between the *quantity,*
nsity, of electricity which may be called into
electrical machine develops electricity of
ty, but of sparing *quantity;* the Galvanic
he other hand, produces a large *quantity* of
t it is of feeble *intensity.* The term *intensity,*
otes the *degree* of excitement exhibited by
body. Various instruments, called *Electro-*
en contrived for measuring the intensity with
ns and repulsions of this kind are exerted;
indicated by the distance to which a sub-

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lements of Chemistry , 151.

stance of determinate size and form is repelled, when subjected to the influence of an electrified body. One of the instruments, which is called the *Quadrant Electrometer*, acts by the divergence of a slender rod of light wood A, terminated by a pith ball, from a stem of wood B, which is screwed into the prime conductor. An ivory quadrant or semicircle C is fixed to the upper part of the stem, having its centre coinciding with the axis of motion of the rod, and serving as a graduated scale. The degree of intensity is indicated by the distance to which the ball is repelled from the stem. Another of these instruments, called a *Gold Leaf Electrometer*, affords a most delicate test of the nature of the electrical excitement. It consists of a glass cylinder cemented below upon a brass plate, and covered above by another plate of the same material. Two pieces of gold leaf are suspended from the upper plate, and a slip of tinfoil is fastened on each side of the glass case to carry off the electricity when the gold leaves diverge so far as to come in contact with them.

Fig. 34.

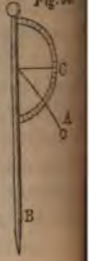
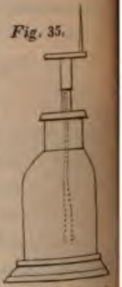


Fig. 35.



73. *Production of Heat and Light.*—On applying th hand or any conducting substance to the prime conductor an electrical machine, a spark is produced. A still mor brilliant spark is observed on discharging the Leyden jar. In *common electricity*, there is no production of heat, wh the fluid moves through a perfect conductor, and meet with no obstruction, but in its passage through imperfect conducting substances, both heat and light are develop Light and Heat are evolved by *Voltaic batteries* of suffici intensity. As the wires are brought together, a spark a pears before actual contact has taken place, owing to *transference* of electricity through the air; a spark

pears every time the contact of the wires is broken. The olution of heat may be perceived on uniting the poles of a ttery in a vessel of water containing a thermometer: the mperature of the water is soon raised, and, on continuing e experiment, will reach the boiling point. If the current conveyed along metallic wires, or wires terminating charcoal, the wires become fused, the charcoal presents a vid white light; in the latter case, on withdrawing the tremities of the conductors from each other, to an interval about four inches, an arch of light of dazzling brilliancy pears between them. This phenomenon is represented in e subjoined figure, in which *a* and *b* are the poles of the

Fig. 2.

ttery with pieces of charcoal attached to them, and beeen these is the ascending arch of light. In the battery the Royal Institution, any substance held in this arch came instantly ignited; platinum, one of the most insible of all the metals, melted in it as readily as wax in candle; quartz, sapphire, magnesia, and lime, were fused; and points of diamond and plumbago rapidly dispeared, as if they had been evaporated by heat. The *ating* effects of Voltaic electricity appear to depend on the nducting power of the substance employed, the heating in an inverse ratio to the conducting power. This is rikingly shown in passing the current through a chain mposed of alternate links of platinum and silver: the atinum will be intensely ignited, while the silver will be arcely warmed. If the poles of the battery are made to rminate in metallic leaves, instead of charcoal, the leaves ill burn with various *colours*: gold yields a white light nged with blue; silver, a brilliant emerald-green light; pper, a bluish-white light with red sparks; lead, a purple light; zinc, a brilliant white light inclining to blue and fringed with red. The light produced by Voltaic electricity cannot be attributed to combustion, as it occurs in gases which contain no oxygen, and even under water; it is also found that neither the gas nor the charcoal has undergone any chemical change. In experiments of this kind with the Voltaic battery, a small number of very large plates is found to be more effectual than a large number of small plates.

74. *Effects of Electricity upon the Magnet.*—The science of *Electro-magnetism* dates from the discovery of Oersted, in 1819. 1. On connecting the poles of a powerful Galvanic battery by a *uniting wire*, and placing a freely-suspended magnetic needle, horizontally and in a parallel direction, *beneath* the wire, he found that the needle immediately changed its position. The *law* of its motion was thus stated: 'That end of the needle which is situated next to the negative side of the battery, or towards which the current of positive electricity is flowing, immediately moves to the westward.' 2. On placing the needle *above* the wire, the same end of the needle moves to the east. Hence the following *formula* was stated: '*The* pole *above* which the *negative* electricity, enters, is turned to the *west; under* which, to the *east*.' The *extent* of the declination caused by a Voltaic circle depends upon its power, and the distance of the connecting wire from the needle; with a powerful battery, and at a small distance, it amounts to an angle of 45°. 3. When the uniting wire is placed in the same horizontal plane as the needle, no declinations to the east or west take place; but the pole of the needle next to the negative end of the wire is depressed when the wire is placed on the west side of it, and elevated when the wire is on the east side. 4. When the uniting wire is placed at right angles to the needle, either above or below it, the latter remains at rest, unless the wire is brought close to one of its poles, in which case the pole is elevated when the negative end of the wire is at the west of the needle, and depressed when it is at the

ast. 5. Lastly, the uniting wire may be placed in a vertical lirection, the needle remaining horizontal: when, with its ipper extremity negative, it is placed exactly between the nagnetic poles, no effect is produced; on moving it nearly midway towards either pole, the needle is attracted; on bringing it close to either pole, the needle is repelled; when the upper extremity of the wire is positive, the phenomena are reversed. These effects of the uniting wire take place through plates of glass, metal, stone, wood, resin, earthenware, or water.—Iron is rendered immediately magnetic by passing electricity from a Galvanic battery through a copper wire wound round it. If a piece of iron, round which a copper wire covered with silk thread has been coiled, be made to touch the poles of a horse-shoe magnet, the copper wire is found to be electrically excited at the moment when the contact is made, and is capable of producing a spark at the instant when its extremities are connected together. These are the *leading facts* of the science; further details may be found in the various treatises on *Electro-dynamics*.

75. *Chemical Effects of Electricity.*—The electricity produced by the electrical machine is generally allowed to be identical with that produced by the Galvanic pile; their chemical effects are, however, remarkably different, and this is explained by comparing the *quantities* of electricity produced by each. An electric battery of fifteen jars, each containing 234 square inches of glass coated on each side, and charged by thirty turns of a powerful plate electrical machine, fifty inches in diameter, yields no more electricity than a platina and a zinc wire, each 1-18th of an inch in diameter, placed 5-8ths of an inch deep in a diluted acid composed of one drop of sulphuric acid and four ounces of water, during three seconds. Again, the quantity of electricity associated with the elements of bodies in their various chemical combinations is so great, that, while electricity sufficient to decompose a grain of water can be easily procured during the chemical action of a few grains of zinc on a diluted acid, Dr. Faraday has inferred that no less than

800,000 charges of the electric battery just mentioned would be necessary to produce the same effect.

76. The *chemical effects* of the Voltaic battery were first exhibited by Messrs. Nicholson and Carlisle, in the *decompositions* which it produces. On immersing the wires into a cup of water, without contact with each other, the water is decomposed, its hydrogen is separated at the negative, its oxygen at the positive, pole. By wires of gold or platinum, the oxygen is obtained pure; with those of the more oxidable metals, it combines, and is converted into an oxide. Various substances are capable of being decomposed by the same agent, and it has been found that the *alkalies* are always separated at the *negative*, the *acids* at the *positive* pole, or extremity of the wire. Davy found that oxygen and hydrogen were separately disengaged from two glasses of water, even when communicating together by vegetable or animal substances. He then operated upon other compounds, and found that sulphur and metallic substances appeared at the negative pole, and oxygen and nitrogen at the positive pole, although the bodies containing them were separate from each other. Under the influence of electricity, an element may have its ordinary power of combination suspended, and be passed through bodies for which it has an affinity, without combining with them. Thus, acids were found capable of being *transferred* through alkaline solutions, and alkalies through acid solutions, to their respective poles. Davy also succeeded in decomposing potash and soda, proving that the two fixed alkalies are metallic oxides. He then analysed the earths, and obtained the four metals, barium, strontium, calcium, and magnesium, from the earths in which they are found. It was afterwards found that all the bases of the earths, except silica, are metallic, and capable of combining with iron.

77. It appears that different bodies have a peculiar relation to electricity, so that, when separated from their combinations with other bodies, they are attracted to the positive or to the negative pole of the battery. Hence, bodies have been dis-

uished by Berzelius into *Electro-negatives*, or those ch pass to the positive pole, and *Electro-positives*, or se which pass to the negative pole. These terms denote t, during decomposition, bodies exhibit a different electric dition from that of the pole at which they appear. The owing table presents the elementary substances, as they affected in this respect:—

Electro-Negatives.

Oxygen
Sulphur
Nitrogen
Chlorine
Iodine
Fluorine
Phosphorus
Selenium
Arsenic
Chromium
Molybdenum
Tungsten
Boron
Carbon
Antimony
Tellurium
Columbium
Titanium
Silicium
Osmium
Hydrogen

Electro-Positives.

Potassium
Sodium
Lithium
Barium
Strontium
Calcium
Magnesium
Glucinium
Yttrium
Aluminium
Zirconium
Manganese
Zinc
Cadmium
Iron
Nickel
Cobalt
Cerium
Lead
Tin
Bismuth
Uranium
Copper
Silver
Mercury
Palladium
Platinum
Rhodium
Iridium
Gold

When a compound, consisting of two bodies arranged in the same list, is decomposed, its elements are found to be electro-positive or electro-negative in regard to each other. Thus oxygen is always separated from any substance in the same list, at the positive pole; potassium, from any substance in the same list, at the negative pole. Oxygen is the most electro-negative, potassium the most electro-positive, of all known bodies.

78. The electric current formed by the *contact* of two metals, *increases*, in one of them, the tendency to affinity for some element of the solution, and *decreases* proportionably that tendency in the other. Upon this principle was founded Davy's attempt to preserve the copper sheathing of ships. 'My results,' he observes, 'are of the most beautiful and unequivocal kind; a mass of tin renders a surface of copper, 200 or 300 times its own size, sufficiently electrical to have no action on sea-water.' He found that cast iron was the best metal for protecting the copper, and that when the surface of the former was from 1-20th to 1-110th part of the surface of the latter, the copper underwent no corrosion; with small protectors from 1-200th to 1-400th of the copper surface, the loss of copper increased as the protectors diminished; and when the protectors were only 1-1000th of the copper surface, a certain proportion of the copper was still preserved. A piece of zinc of the size of a pea was found sufficient to protect 40 or 50 square inches of copper, in whatever part of the latter surface it was situated. It was discovered, however, that the protection of the copper sheathing was accompanied by adhesion of sea-weeds and shell-fish, by chemical changes in the protectors, and foul depositions on the copper. It is stated that 'the iron protectors in the *Glasgow* were converted into a substance like plumbago, which could be cut by a knife. A portion of this wrapped in paper was placed by a shipwright in his pocket for examination; the new substance at first became warm, but it soon grew hot, and in a short time passed into a state of absolute ignition by the

action of the air.' It therefore remained to be proved to what *extent* the copper should be protected in order to secure the desired effect. The plan was abandoned in 1828.

79. Dr. Faraday has lately introduced some new terms explanatory of his views of electro-chemical decomposition. He considers that what are called the *poles* of a Voltaic battery possess no attractive or repulsive powers, but merely furnish a passage to the electrical current. He therefore employs the synonymous term *electrodes* (from ἤλεκτρον, and ὁδὸς, a way). The electric currents are supposed to circulate round the earth in a direction from east to west; hence, if a body to be decomposed be similarly placed, the point or surface at which positive electricity *enters*, is termed the *anode* (from ἀνα, upwards); the point or surface out of which it *passes*, is called the *cathode* (from κατὰ, downwards). Substances directly decomposable by electricity, are called *electrolytes* (from ἤλεκτρον, and λύω, to set free); their decomposition is therefore termed electrolyzation. The elements of an electrolyzed body are called *ions* (from ἰὸν, going); that which appears at the anode, commonly called the electro-negative element, is termed *anion;* that which appears at the cathode, or electro-positive element, *cation*. Thus, if water be electrolyzed, oxygen and hydrogen are ions—the former an anion, the latter a cation.

80. *Effects of Electricity on Animals.*—Electricity of great intensity, as that of lightning, produces immediate death. When applied in small quantity, it is found useful in diseases of a paralytic kind, and in cases of suspended animation. The part of the body to which the stimulus is to be applied, must form part of the circuit through which the electricity passes; the connexion is effected by means of metallic rods, brass chains, and the common discharger. Some fishes have the power of giving electric shocks, the effects of which are the same as those procured by the friction of an electric. The Torpedo, when touched with both hands at the same time, one on the upper, the other on the lower surface, gives a shock like that of the Leyden jar, the two

surfaces of the fish being in the same condition as the inner and outer coatings of the jar. The Gymnotus electricus, or electrical eel, possesses the electrical powers of the torpedo in a higher degree; when small fish are placed in water with this animal, they are generally stunned, and sometimes killed, by the shock it is capable of imparting.

RECAPITULATION.

57. What are the most striking phenomena of Electricity in Nature?—59. Which are the best *Conductors* of Electricity? Which are the best *Non-Conductors?* How are buildings best secured from the Effects of Lightning? By what circumstances is the conducting power of most bodies influenced? What is the *Electric Circuit?*—60. What is an *Electroscope?*—61. Explain Franklin's theory of Electricity. Explain the theory of *two fluids*. What is *resinous*, and what *vitreous*, Electricity? Explain the terms *negative* and *positive*, as applied to this agent.—62. Give an instance of Electrical Excitement by *friction*. Explain the apparatus called the *Electrical Machine*. What are the phenomena produced by its action?—63. Give an instance of electric excitement, as produced by change of *temperature*.—64. Give an instance of the same, as produced by change of *form*.—65. How is it shown that Electricity is excited by *chemical action?*—67. What is the meaning of *induction?*—68. What is the principle of the *Leyden jar?* In what does an *electrical battery* consist?—69. What is Galvanism? How is a *Voltaic Circle* formed?—71. Explain the *Electro-chemical* theory of Davy.—72. What is meant by *intensity* of Electricity? What is an *Electrometer?*—73. What are the comparative powers of *Common Electricity* and of *Voltaic Electricity*, in the production of heat and light?—74. What effects are produced by Elec-

city upon the *Magnetic Needle?*—75. What are the
mparative *quantities* of Electricity produced by the *Elec-*
cal Machine and by a *Voltaic Battery?*—76. Mention
ne of Davy's discoveries, as effected by means of Vol-
e Electricity.—77. What is the meaning of an *Electro-*
itive, and of an *Electro-negative*, element?—78. Describe
vy's invention for protecting the copper sheathing of
ips.—79. Explain the new terms introduced by Dr. Fara-
y.—80. What are the effects produced by electricity on
imals?

SECTION II.

CHEMISTRY OF INORGANIC SUBSTANCES.

CHAPTER IV.

OF CHEMICAL ACTION.

81. *General Remarks.*—The *physical* properties of matter have been already briefly noticed (p. 8). There are, however, other forces in nature, which belong more exclusively to the science of Chemistry, and which, with reference to the materials of which our globe is composed, produce effects equal in importance and interest to any other. 1. If water be mixed with water, or salt with salt, the effect is merely an increase of *quantity;* no change of *quality* is produced. 2. If a blue and a yellow powder be mixed together, a green powder is produced; but this is merely an effect impressed upon the eye by the intimate *mixture* of the yellow and blue light which is separately reflected from the minute particles of each; these particles may be separated mechanically, and the powders restored to their former appearance. 3. If two coloured liquids, having no chemical attraction for each other, be mixed together, a liquid of a different colour is produced, and the two ingredients cannot, it is true, be mechanically separated; yet, even in this case, the liquid is a mere *mixture*, and its properties are accordingly intermediate between those of the liquids mixed. In these three cases there is *no change of property*, nor is any new property

superadded. But when potash dissolved in water, is mixed with tartaric acid also dissolved in water, a solid substance, cream of tartar, is thrown down in the vessel; this substance is neither potash nor tartaric acid, nor can either of these substances be again procured from it; the liquid also from which it subsided, no longer presents the qualities of the ingredients which were mixed in it, but those of a *new* and entirely *different* substance. The potash and tartaric acid have, therefore, *united* with each other, to form a *chemical compound*, which, when carefully collected, is exactly of the same weight as the ingredients possessed before their union, but of entirely different qualities. The force by which this new substance is formed is called *chemical attraction* or *affinity*—a force of the highest importance in Chemistry, inasmuch as the whole science includes little more than a knowledge of the laws and effects of chemical attraction and repulsion. The duty of the chemical philosopher is to investigate the various compositions and decompositions of matter, as effected by these forces; to inquire into the circumstances which can influence them; and to determine, modify, or suspend their operation by the application of heat, light, electricity, and other agents which are capable of promoting these effects. In all chemical operations, to use the words of Paley, 'our situation is precisely like that of an unmechanical looker-on, who stands by a stocking-loom, a corn-mill, a carding machine, or a threshing machine, at work, the fabric and mechanism of which, as well as all that passes within, is hidden from his sight by the outside case; or if seen, would be too complicated for his uninformed, uninstructed understanding to comprehend.' He sees, at one end, a material enter the machine; at the other end, he sees the material issuing from it in a *new* state—a state manifestly adapted to future use. What he *sees* is sufficient. The effect upon the material, the change produced in it, the utility of that change for further applications, abundantly testify the hand and agency of a Contriver.—*Natural Theology*, ch. vii.

82. The subject of *Chemical Action* may be arranged and studied under the following divisions :—

- I. PHENOMENA OF AFFINITY.
    - 1. *Single Elective Affinity.*
        - *Decomposition.*
    - 2. *Double Elective Affinity.*
        - *Double Decomposition.*
- II. CHANGES INDUCED BY CHEMICAL ACTION.
    - 1. *Change of Properties.*
    - 2. *Change of Density.*
    - 3. *Change of Temperature.*
    - 4. *Change of Form.*
    - 5. *Change of Colour, Smell, Taste, and Sound.*
- III. CAUSES WHICH MODIFY AFFINITY.
    - 1. *Cohesion.*
    - 2. *Elasticity.*
    - 3. *Quantity of Matter.*
    - 4. *Gravity.*
    - 5. *The Imponderables.*
- IV. LAWS OF CHEMICAL COMBINATION.
    - 1. *Chemical Equivalents.*
    - 2. *Atomic Theory.*
        - *Theory of Volumes.*
        - *Isomeric Compounds.*
- V. CHEMICAL NOMENCLATURE.
- VI. CHEMICAL SYMBOLS.
- VII. CRYSTALLIZATION.
    - 1. *Isomorphous Bodies.*
    - 2. *Dimorphous Bodies.*
    - 3. *Plesiomorphous Bodies.*

I. PHENOMENA OF AFFINITY.

83. The *physical* property of Attraction by Gravitation operates between masses of matter, and at great distances;

that of Attraction by Cohesion operates between the minute particles of a body, preserving it in an entire state. By the former of these agencies, a mass of marble falls to the earth from any height in the atmosphere; by the latter, each particle of marble retains its position in the mass. These effects are entirely independent of the intimate nature of the substance; they occur, in a greater or less degree, in all bodies possessing *weight*. But if a minute particle of marble be subjected to *chemical action*, it will be found to consist of three substances, incapable of being separated from each other by mechanical means, and presenting, when separated by chemical action, properties quite distinct from those of marble. These three substances are, therefore, preserved in a state of union, in the form of marble, by a peculiar force, termed *Affinity*, or *Chemical Attraction*. Different bodies are affected by affinity in different degrees. 1. Water combines readily with alcohol, feebly with ether, and scarcely at all with oil. 2. Sugar dissolves readily in water, sparingly in alcohol; while camphor dissolves freely in alcohol, and sparingly in water. 3. A rod of gold, plunged into a vessel of water, and then withdrawn, retains but little of the liquid on its surface, and this may be easily removed; but, on repeating the experiment with mercury, a coating of this metal adheres to the rod, and cannot be removed; the gold is rendered white, and, if the surface be scraped, the portions thus removed contain gold and mercury united by chemical attraction. 4. A piece of tin may be made to float on melted lead; but, as the tin melts, it becomes intimately united with the lead, and each particle of the compound, when solid, will be found to consist of both metals; in this case, the force of attraction counteracts that of gravitation. 5. The air inhaled in the act of respiration is different from that which is exhaled; on breathing through a tube into lime water, a *combination* takes place between the carbonic acid, an ingredient of the exhaled air and the lime, and a white substance, chalk, is formed in the liquid.

84. *Single Elective Affinity.*—The simple combination of two substances, which have an affinity for each other, is of familiar occurrence, and is readily understood. But chemical combination is frequently attended by peculiar phenomena, which are not so simple. 1. There are three substances in general use, magnesia, lime, and nitric acid, commonly called aqua fortis. The nitric acid has an affinity for magnesia, and will combine with it; it has also an affinity for lime, and will also combine with it. On mixing these three substances together, in equal quantities, it might, therefore, be expected that they would all combine together. The result, however, is that *only one* of the affinities is obeyed: the nitric acid combines with the lime, leaving the magnesia uncombined and altogether unaffected. This case not only affords a further illustration of the principle laid down in the preceding paragraph—that different bodies are affected by affinity in different degrees—but it exemplifies a *preference*, or choice, which bodies evince, in combining with one substance, and rejecting others. This phenomenon was termed by Bergmann *Single Elective Affinity*. 2. Upon the same principle the formation of a compound is frequently attended by the *destruction* of a previously existing compound, as when some third body acts upon a compound, for one element of which it has a greater affinity than for the other. This may be illustrated by the above-mentioned bodies. If the nitric acid be already combined with the magnesia, and the lime be added to the compound, the result will be that the magnesia will be separated from the lime, which will take its place, and combine with the acid; the magnesia, which was formerly dissolved in the acid, and invisible, will re-appear and be perfectly separate. The former compound is decomposed; and this process is termed *decomposition*. 3. If camphor be dissolved in alcohol, and the solution be poured into water, the alcohol quits the camphor, and combines with the water; the camphor is thus set free, and appears as a separate body. 4. If sulphuric acid be added to a combination of nitric acid and baryta, it separates the

baryta, leaving the nitric acid free. In each of the three last cases, combination and decomposition take place. The order in which these decompositions occur, may be expressed in tables, as in the following, by Geoffroy:—

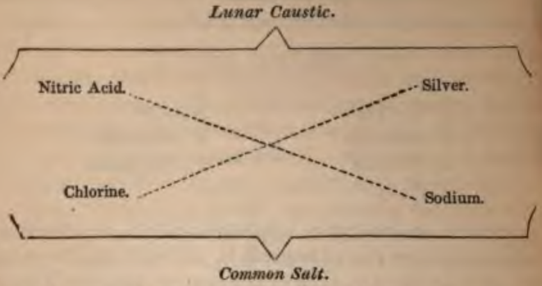
Sulphuric Acid.

1. Baryta
2. Strontia
3. Potassa
4. Soda
5. Lime
6. Ammonia
7. Magnesia.

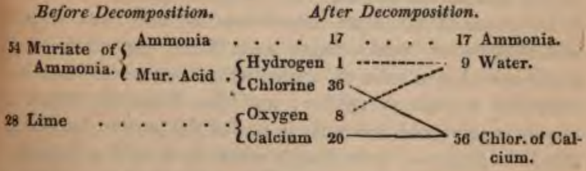
According to this table, sulphuric acid has an affinity for all the substances placed beneath it, and will combine separately with each; and each of the compounds, thus formed, may be decomposed by adding to it any of the substances placed above it in the table. Thus, ammonia will separate magnesia from sulphuric acid, lime will separate ammonia, and soda lime; but magnesia will not separate ammonia, nor ammonia lime, nor will any of them separate baryta from sulphuric acid. This *order of decomposition* does not, however, represent the comparative *forces of affinity;* other causes are in operation which modify the force of affinity to such a degree, that the amount of the effect produced by this power cannot be determined. The table, therefore, represents the order of decomposition, not that of affinity.

85. *Double Elective Affinity.*—Affinity is frequently the cause of still more complicated changes. In those above described, three substances only were present, and *two* affinities in operation. But when two compounds are mixed together, both of them may be decomposed, and *four* affinities exhibited. 1. *Lunar caustic* consists of nitric acid and silver; *common salt* consists of chlorine and sodium. On mixing a solution of these compounds together, the nitric acid leaves the silver, and combines with the sodium, forming a salt which remains in solution; on the other hand, the chlorine quits the sodium, and combines with the silver, forming a curdy substance, which falls to the bottom of the containing

vessel. These *changes* may be represented by the following *diagram* :—



In this case, the nitric acid and the chlorine have each an affinity for the silver and the sodium; but the nitric acid *prefers* combining with the sodium, to remaining in combination with the silver; and a corresponding *preference* is exhibited by the chlorine. The previous combinations are, therefore, destroyed, and two new ones produced; the results are the formation of two new compounds, viz. nitrate of soda, and chloride of silver. This process is termed *double elective affinity;* and it is accompanied by a *double decomposition.* Mr. Kirwan applied the terms *quiescent* and *divellent* to denote the tendency of the antagonist affinities, the action of the former being to prevent a change, that of the latter to produce it. Where the total sum of the devellent affinities is stronger than that of the quiescent, decomposition necessarily takes place. The effects which have been described cannot be attributed to the sole influence of affinity; other circumstances appear, as in the case of single elective affinity, to conspire in producing the results. 2. The following example of a more complex action is illustrated by a *diagram* constructed by Dr. Reid. ' The names of substances which react on each other, and numbers representing the proportions, are placed on the left, one above the other. When any of these are compounds which are decomposed, brackets proceeding from them enclose the names of their elements. Lines traced from these numbers represent the quantities of each, proceeding from the left to the right. Those that proceed from the different elements or compounds that combine together, terminate in a common point; and opposite these, towards the right, are placed the names of the products and their quantities. The annexed figure represents the decomposition which takes place during the preparation of ammonia from the muriate of ammonia by means of lime:—



'The character of the line expresses the different conditions in which the products of any re-action are obtained. When they are gaseous, the lines are dotted, as in those pointing to ammonia. When they are liquid or retained in solution, lines composed of many smaller lines are used, as in those pointing to water. And when any substance is obtained in the solid form, a plain line is drawn. Any variety of form may be given to the diagram, according to the effect which has to be represented.'—*Reid's Text Book of Chemistry.*

II. CHANGES INDUCED BY CHEMICAL ACTION.

86. *Change of Properties.*—Substances which have entered into combination generally exhibit an entire *change of properties:* the elementary ingredients have lost their former properties, and have acquired new ones:—1. *Water*, a liquid, consists of two gases, hydrogen and oxygen, neither of which has ever been compressed into a liquid; hydrogen is one of the most inflammable bodies in nature, but water

cannot be inflamed; oxygen supports combustion wit
brilliancy, but water extinguishes combustion. 2. C
Salt, which is not only harmless, but absolutely ne
for man, consists of two formidable ingredients, viz. th
sodium, and the gas chlorine; either of which tak
the stomach is fatal to life. When presented to each
they burst into flame, and instantly lose their dar
properties. 3. *Glauber's Salt,* a valuable medic
composed of two caustic poisonous substances, viz.
vitriol, and barilla or soda. 4. The *Atmosphere* we
is composed of the same ingredients as that most
and destructive liquid called aqua fortis, or nitri
5. *Charcoal* is a solid substance which has never b
duced to a state of vapour; and the diamond, w
merely crystallized charcoal, is one of the hardest bo
nature. *Sulphur,* in its simple state, is a solid sub
and requires a high temperature to maintain it in a s
vapour. But when carbon, the pure principle of ch
and sulphur are made to combine, the compound,
of being solid, is a thin liquid, and cannot be fro
rendered solid at any temperature; and instead of
difficult to vaporize, is one of the most evaporable
liquids. 6. *Copper* is a soft metal; *tin* is still softe
the compound is exceedingly hard. 7. Numerous ex
of changes of properties occur in the combination o
with alkalies. *Sulphuric acid,* for instance, and *sod*
sess caustic properties; the former is intensely aci
converts the blue colour of vegetables into red; the
has a pungent taste, and turns the blue colour of vege
into green; on causing the two substances to combine
properties of each are lost, and no effect is produced
compound on vegetable colours; they appear to have *n*
lized each other's properties.

87. *Change of Density.*—Chemical action is gen
accompanied by *change of density.* Bodies which have
bined, rarely occupy the same space which they filled
separate. 1. A pint of spirit and a pint of water,

together, occupy *less* space than two pints. 2. *Olefiant gas* consists of elements, which, when set free, expand to four times the bulk they occupied in the compound. 3. *Copper* is a light metal; *tin* is still lighter; but the compound is much heavier, bulk for bulk, than either. Glauber observes that if two balls of copper, and two of pure tin, of one and the same form and quantity, and of known weight, be melted together, and the melted mixture be poured into the mould of the first balls, scarcely three balls will be produced, though the weight of the four will be preserved. In these cases, the bulk is *diminished*, by combination. Some *gases*, however, exhibit no change of density under similar circumstances; in the formation of some gases, there is an extraordinary *increase* of bulk. When water, for instance, is decomposed, and made to assume its elementary gaseous form, there is an increase of bulk nearly equal to 2,000 volumes. A cubic inch of water contains 662 cubic inches of oxygen, and 1325 cubic inches of hydrogen; its volume is therefore increased 1987 times by the decomposition. In some *metallic* compounds, the bulk is also *increased* by chemical action.

88. *Change of Temperature.*—When chemical action produces diminution of bulk, without a change of form, it is accompanied by a *change of temperature*. If a *pint of sulphuric acid* be mixed with a *pint of water*, the chemical action is so powerful as to raise the thermometer above the boiling point; the compound rises in temperature, owing to its having less capacity for heat than its ingredients possessed separately. But the intense heat which is sometimes evolved by chemical action, cannot be explained upon the principle of a change of specific heat. Change of temperature also occurs, when the combining bodies undergo a change of form, as when a *gas* is condensed into a *liquid*, or a *liquid* into a *solid*. If water be poured upon lime, the two substances combine, the water loses its liquid form, and the lime swells, becomes hot, bursts, and is converted into what is called slaked lime. The production of *cold*, during combination,

occurs only when heat is rendered insensible by a change of form, as on the conversion of a solid into a liquid, of a liquid into a gas. It is upon this principle that freezing mixtures are formed (p. 44).

89. *Change of Form.*—Chemical Action is attended by *change of form.* 1. *Gases* may form *liquids*, as when hydrogen and oxygen combine to form water. On applying a flame to a mixture of these gases, explosion takes place, attended with the evolution of great heat, and the elastic *gaseous* mixture is condensed into the *liquid*, water. 2. *Solids* may form *liquids*, as when carbon and sulphur combine, as has been already noticed. A nearly liquid substance is formed when equal parts of alum and sugar of lead are bruised together in a mortar. These substances contain a quantity of water, which is set free by the friction, and occasions the partial fluidity of the mixture. 3. *Liquids* may form *solids*, as when sulphuric acid is mixed with a solution of muriate of lime in water. Muriate of lime consists of muriatic acid and lime, and is readily soluble in water; sulphuric acid has a stronger affinity than muriatic acid for lime; it therefore combines with it, and forms a compound which is nearly insoluble in water, and which, in a spongy form, occupies the whole of the vessel. *Solids* are formed from *liquids* when a new substance *subsides* on mixing two solutions, as those of potash and of tartaric acid; the subsiding substance is insoluble in the liquid, and, in consequence of its being *thrown down*, is called a *precipitate.* 4. *Solids* may form *gases*, as when a vast quantity of gaseous matter is produced on igniting gunpowder, and attended by the phenomenon of *detonation;* or a gas may be more slowly disengaged by the action of a liquid upon a solid, and be attended by *effervescence*, as when marble is placed in hydrochloric acid. 5. A *gas* and a *metal* may form a *solid*, as when chlorine and sodium combine to form common salt.

90. *Change of Colour, Smell, Taste, and Sound.*—Chemical Action is frequently attended by *change of colour.*

o uniform relation, however, exists between the colour of
e compound and of its ingredients. Copper is of a *red-*
sh-brown colour, and tin is *white ;* but the compound, in-
ead of being of a paler reddish-brown colour, is *grey*.
he brown oxide of copper generally gives rise to green and
ue-coloured salts; while the salts of the oxide of lead,
hich is itself yellow, are for the most part colourless. The
hite metal zinc, and the *red* metal copper, when melted
gether, form the *yellow* compound brass. The vapour of
dine is of a *violet* colour; but it forms a *red* compound
ith mercury, and a *yellow* one with lead. Charcoal is the
ackest of substances; sulphur is *yellow ;* but the com-
und is *colourless* as water.—In this compound a new *smell*
d *taste* are acquired; there is, in fact, not one point of
semblance to the elements of which it is composed. When
tric acid is made to act upon sugar, the *sweetest* of all sub-
ances, a powerful *acid*, the oxalic, is produced.—Another
ry remarkable change, produced by the combination of
etals, is that of *Sound*. If three bells be cast from the
me mould, one of copper nearly pure, the second of good
n, and the third of a mixture of both; the first will have
dull heavy sound, the second scarcely any sound at all,
hile the third will have a clear musical sound. Hence,
ll-metal is a compound of tin and copper.

III. CAUSES WHICH MODIFY AFFINITY.

91. *Cohesion.*—Chemical Action takes place only between
e minute *particles* of matter; it is, therefore, obviously
pposed by *Cohesion*. 1. If a piece of iron and a piece
f sulphur be brought together, no chemical action
kes place. If the iron be reduced to filings, and the
lphur to powder, and both be mixed, still no change
kes place. But, if this mixture be melted by heat, com-
ination takes place, and a new substance is formed. Hence,
appears that *Cohesion is the antagonist of Affinity*, owing

to its property of preserving bodies in a *solid* stat
that the *liquid* state is favourable to the exertion of A
by permitting the closest approximation of the part
matter. 2. On the other hand, *Affinity is the antag*
Cohesion. A piece of marble will not dissolve in wa
the cohesion among the particles of the marble is
and the affinity between the marble and the wate
But if very strong vinegar be added, the greater aff
this substance operates against the cohesion of the
which accordingly begins slowly to dissolve; if the
ance of cohesion be lessened by the application o
the force of affinity prevails still more by the dimin
the antagonist power, and the marble dissolves with
The *operation* of affinity is favoured by mechanical *d*
as well as by the application of *heat;* by the former
the extent of surface is increased; by the latter,
faction is produced.

92. The best mode of ensuring chemical action is
duce both substances to the *liquid* state by heat; i
cases it is sufficient if *one* of the substances is in
state, as is proved by the facility with which water d
many salts and other solid bodies.—The *force of c*
has been supposed, in many cases, to determine the r
chemical action, even in opposition to affinity. 1. I
of *single elective affinity*, if three substances be mi
gether, as two acids and an alkali, of which each a
an affinity for the alkali, *that* acid will be selected
forms an *insoluble* compound with the alkali, and th
will be rejected. If lime be added to a compound
bonic acid and ammonia, it separates the acid and co
with it; the reason alleged is, that the former con
was soluble, the new one is insoluble. 2. In cases of
elective affinity, if four substances be mixed together,
of forming four compounds, *that* compound will su
produced, which assumes the *insoluble* state. Th
phuric acid, soda, nitric acid, and baryta, may produ
compounds; of these, the compound of sulphuric a

yta is insoluble, and is immediately formed; this, obvi- ly, prevents the formation of two of the compounds, and essitates the formation of the remaining one. Thus, also, compound of nitric acid and lime is decomposed by the pound of carbonic acid and ammonia; the former com- nds were soluble, one of the new ones is insoluble.—The nomena of *crystallization* depend on the predominance of esion over affinity.

3. *Elasticity.*—When it is considered how cohesion nteracts the tendency of affinity by preserving the *solidity* odies, it might be supposed that the *gaseous* state is very urable to chemical action. It is true that an air or a is totally devoid of cohesive attraction; but such bodies sess a property, of a very opposite nature indeed, but ch equally antagonises the tendency of affinity, and is n overcome only by great difficulty. This is a repulsive ncy, called *Elasticity;* its tendency is to keep the ticles of a body at a distance from each other, so that bination is prevented. Oxygen and hydrogen have rong mutual affinity, but they may be preserved together any length of time without combining. This is true hlorine and hydrogen. But when the distance between particles of such bodies is overcome by mechanical force, bination sometimes takes place with facility, and even h violence. When this cannot be effected, many gases capable of combining readily while in their *nascent* state, t is, at the moment of their acquiring the gaseous form the decomposition of some solid or liquid of which they ned an ingredient. Elasticity is also a *decomposing* *nt.* Gaseous bodies, of feeble mutual attraction, as orine and nitrogen, which have been made to combine by siderable condensation, may be readily decomposed; a ht elevation of temperature, or the contact of a substance ich has an affinity for either of them, causes an immediate losion. For the same reason, all compounds which con- a *volatile* and a *fixed* principle, are liable to be decom- ed by a high temperature. Some of the decompositions

formerly ascribed to the sole influence of elective may be attributed to elasticity. If three substa mixed together, capable of producing two compou of which is more volatile than the other, the *more* compound will generally be formed and driven of agency of heat. Some cases of double decomposit be similarly explained. From what has been said and in the preceding paragraph, it appears that the i of *Heat* varies in respect to chemical action; that times *increases*, at other times *diminishes*, the affinity. Its modes of action are, however, consist each other:—1. it favours affinity by diminishing c 2. it prevents composition, by keeping the particles at a distance from each other; or, by producing ex it tends to separate from each other substances combined.

94. *Quantity of Matter.*—The force of affinity influenced by what is called *Quantity of Matter.* 1. position is more easily effected, in proportion to t quantity of any ingredient combined. Thus, oxy bines with lead in three different quantities; the c which contains the largest quantity of oxygen is composed by the action of heat; a higher tempe required to decompose the second compound; strongest heat of a furnace will not decompose the may therefore be stated, that the larger the quanti ingredient combined with another, the more easily tion of it separated. 2. In forming *solutions*, it that equal quantities of the substance to be dissolved successively more difficult of solution, until the af tween the solvent and the solvend is entirely satis solution is then said to be *saturated*, and no mo dissolved, unless the temperature be raised. It m fore be stated that the less the quantity of a substa bined with another, the more readily does an quantity enter into combination. 3. The larger the of a substance employed in chemical operation,

speedily will the action be effected. Thus, in separating an acid from a compound by means of an alkali, a larger quantity of this alkali is employed than is necessary to saturate the acid; by this means every particle of the substance to be decomposed is subjected to the action of the alkali. Very different products are, however, sometimes obtained, according to the quantity of the substance used.

95. *Gravity.*—The influence of *Gravity* resembles that of cohesion in masses, in preventing that intimate mixture which favours chemical action. Hence, when two bodies differ in specific gravity, their combination is opposed. Oil floats on water, and refuses to combine with it, being specifically lighter. Salt sinks in water, being heavier; and it is only by agitating the solution, that the salt can be equally diffused throughout it. In melting together metals of different specific gravities, it is necessary to stir the mixture, to prevent the heavier metal from subsiding to the bottom.

96. *Specific Gravity.*—The specific gravity of a body is its *density*, compared with the density of another body which is assumed as the standard. This standard is pure water, at the common temperature. 1. In order to determine the specific gravity of a *solid*, it is necessary, first, to weigh it in common scales in the air, and then to weigh it in water by the apparatus represented in the figure. A body, so immersed, *loses* of its weight a quantity precisely equal to the weight of its own bulk of water; and hence, by comparing this weight with the total weight of the solid, its specific gravity is ascertained. The rule, therefore, is to divide the total weight in air by the *loss* of weight in water; the quotient gives the specific gravity. If, for instance, a piece of lead weighs, in the *air*, twenty-two grains, and only twenty in *water*, the loss is two grains, and this is exactly equal to the weight of a quantity of water equal to the lead in size. As 2,

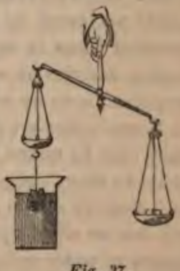


Fig. 37.

therefore, the loss of weight in water, is to 22, the total weight in air, so is 1, the standard of unity, to 11, the specific gravity of lead. 2. The specific gravity of a *liquid* body is more easily ascertained, by filling a small bottle of known weight with it, and with water, successively, and weighing them. 3. The specific weight of a *gaseous* body is ascertained by comparing it with atmospheric air. The first step is to find the weight of a given volume of air. For this purpose a flask provided with a stop-cock, is weighed when full of air; the air is then withdrawn by means of the air-pump, and the flask is again weighed; the difference between the two weights is that of the volume of air. By similar means the weight of any gas may be found, and its specific gravity, with reference to atmospheric air, be determined.

97. *The Imponderables.*—The influence of the *Imponderables* upon chemical action has been sufficiently explained in the chapters on Heat, Light, and Electricity. The last of these agents is frequently employed to effect the combination, and sometimes the decomposition, of gaseous bodies. It appears to act by the heat which is evolved.

IV. LAWS OF CHEMICAL COMBINATION.

98. *General Remarks.*—Affinity being a property probably possessed by all bodies, it is important to ascertain whether there is any limit to its operation, whether combination satisfies or weakens its tendency, whether there are any fixed laws by which chemical combination is regulated. 1. Some bodies are found to unite in *any* proportion in which they may be mixed together, as water and alcohol. Others unite in every proportion up to a certain limit; thus, water will dissolve salt in any quantity, up to the saturating point, but has no effect upon any additional quantity. A hundred grains of water will dissolve any quantity of sea-salt which does not exceed forty grains; after this, the cohesion of the salt prevails against its affinity for the water. In all these cases, the affinities are feeble, and the properties of the

mpounds partake more or less of those of their elements.

But there are bodies which combine only in one, or in a
w fixed proportions; and their compounds lose, more or
ss entirely, the properties which characterised their ele-
ents. These are the compounds which exhibit the cha-
cteristic effects of chemical action. Their combination is
gulated by the following *laws* :—

99. *Law* 1.—*The composition of all bodies, whether*
rmed by nature or by art, is fixed and invariable; their
ements are found to exist always in the same relative
antities. 1. A piece of marble always contains the same
lative qualities of carbonic acid and lime, from whatever
rt of the world it be procured. 2. If a portion of lime be
posed for a long time to the atmosphere, it absorbs from
a quantity of carbonic acid; if the weight of the lime be
presented by 100, the weight of the carbonic acid absorbed
ill be 78½; if exposed to the atmosphere for an unlimited
riod, not another particle of the acid will be absorbed.
hese are, therefore, the *fixed proportions* in which these
ements exist in marble, and in limestone; and these ele-
ents are found associated in the same proportions in various
her minerals. 3. Water consists of one part of hydrogen
d eight parts of oxygen, by weight; and so invariable is this
le, that water cannot be formed by any other proportions
these elements. 4. Salt, whether obtained from mines,
kes, or the ocean, always consists of thirty-six parts of
lorine gas, and twenty-four parts of the metal sodium.
. Sulphuric acid is always composed of sixteen parts of
lphur and twenty-four parts of oxygen; if these elements
ere made to combine in other relative proportions, some
ther compound might be formed, but *not* sulphuric acid.
his law is of the utmost importance, and constitutes the
ery basis of Chemistry.

100. *Law* 2.—*The relative quantities in which bodies com-*
ine, may be expressed by proportional numbers. Thus,
parts of oxygen combine with 1 part of hydrogen, with
6 parts of sulphur, with 35·4 of chlorine, with 39·6 of se-

lenium, or with 108 of silver. When any of these bodie combine with each other, they combine either in the sam quantities as above stated, or in some multiple of thos quantities, as will be noticed in the following law. Thus 16 parts of sulphur combine with 1 of hydrogen, with 35· of chlorine, with 39·6 of selenium, or with 108 of silve And so of the other bodies.—Upon the principle of this law Wollaston applied the term *Equivalent* to the combinin proportions of elementary, and of compound, substance required to neutralize each other; the combining proportio of one body being considered as equivalent to that of anothe body, and capable of being substituted for it in combinatio Thus, 8 is the equivalent of oxygen, 16 of sulphur, and i these proportions they combine; but if it is desired to produce combination between oxygen and silver, the number will be 8 and 108; and the number 108, which represent silver, is considered to be equivalent to the number 16 which represents sulphur; for either of them combine wit the same proportional number, or equivalent of oxygen.– This law applies not only to *elementary*, but also to *compound*, substances. Water consists of oxygen 8, and hydrogen 1; the equivalent of *water* is therefore 9. Potash consists of potassium 39, and oxygen 8; the equivalent o *potash* is therefore 47. If it be desired to produce combination between these compounds, the combining equivalents will be 47 + 9, and the equivalent of the new compound 56.

101. *Law* 3.—*When a body combines with another bod in more than one definite proportion, the quantity of one o them in the different compounds is found to bear a ver simple ratio to that of the other.* 1. A body may combin with from one to six equivalents of another; in such cases the combining proportion of the second body is always som *multiple* of the first equivalent. Thus, 8 of oxygen combines with 16, or with 32, of sulphur, but with no intermediate quantity; with 108, or with 216, of silver; and s with all other substances. 2. A body may combine wit

alf an equivalent of another body, with one equivalent, vith one and a half, with two equivalents, with two and a ialf, &c. Thus phosphorus combines with half an equivalent of oxygen, or 4, to form one compound; with an equivaent and a half, or 12, to form a second compound; with wo and a half, or 20, to form a third.

102. *Chemical Equivalents.*—Chemical equivalents merely epresent the relative quantities of substances which combine ogether, as referred to some standard of comparison. Hydrogen is generally assumed in this country as the stanlard, the number assigned to it being 1, or *unity*. Dr. Thomson makes oxygen 1, so that hydrogen is eight times less than unity, or ·125. Wollaston made oxygen 10, so that hydrogen would be 1·25. It is of little importance which plan is adopted, provided the relation be strictly observed. The hydrogen may be converted into the oxygen scale, by dividing the former by 8; the oxygen into the hydrogen, by multiplying the former by the same number.

Chemical Equivalents of Elementary Substances.

Elements.	Equivalents.	Elements.	Equivalents.	Elements.	Equivalents.
Aluminium	13·7	Iodine . . .	126·3	Rhodium .	52·2
Antimony .	64·6	Iridium . . .	98·8	Selenium .	39 6
Arsenic . .	37·7	Iron	28	Silicium .	7·5
Barium . .	68·7	Lead	103·6	Silver . .	108
Boron . . .	10·9	Lithium . . .	10	Sodium . .	23·3
Bromine . .	78·4	Magnesium .	12·7	Strontium	43·8
Cadmium .	55·8	Manganese .	27·7	Sulphur .	16·1
Calcium . .	20 5	Mercury . .	202	Tellurium	32·3
Carbon . .	6·12	Molybdenum	47·96	Thorium .	59·6
Cerium . .	46	Nickel . . .	29·5	Tin	58·9
Chlorine .	35·42	Nitrogen . .	14·15	Titanium .	24·3
Cromium .	28	Osmium . .	99·7	Tungsten	94·8
Cobalt . .	29·5	Oxygen . . .	8	Vanadium	68·6
Copper . .	31·6	Palladium .	53·3	Uranium .	217
Fluorine .	18·68	Phosphorus .	15·7	Yttrium .	32·2
Glucinium	17·7	Platinum . .	98·8	Zinc . . .	32·3
Gold . . .	199·2	Potassium .	39·15	Zirconium	33·7
Hydrogen .	1				

103. *Atomic Theory.*—It is possible to conceive that of sand may be divided into a million parts, and each o into a million more, and so on *ad infinitum.* It may ever, be true that a grain of sand cannot be divid more than a certain number of parts, each of which, invisible under our microscopes, possesses such c power as to resist further division. Whether mat infinitely divisible, or consist of ultimate particles *Atoms*, is still a disputed point. The latter opini assumed by Dalton, as the most satisfactory method plaining the foregoing laws of chemical combinati forms the basis of what is called the *Atomic Theory* cording to this theory—

(1.) All bodies consist of *ultimate atoms*, which are same size and shape in the same body, but which d *weight*, in different bodies. The weight of an atom gen is eight times as great as that of an atom of hyd and half as great as an atom of sulphur.

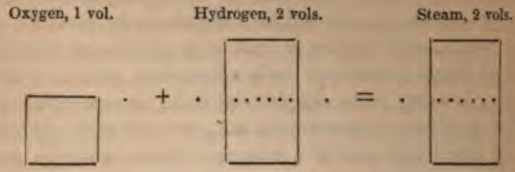
(2.) Chemical combination takes place between the of bodies. One atom of one body may combine with more atoms of another body: thus, one atom of hy combines with one atom of ogygen to form water atoms of oxygen combine with one atom of sulphur t sulphur*ous* acid; while three atoms of oxygen combin one atom of sulphur to form sulphur*ic* acid. Nitrog oxygen combine in the several proportions of from one atoms of the latter, to one atom of the former, gas.

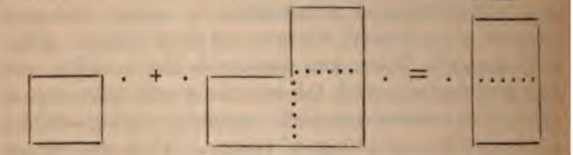
(3.) From these cases it appears that the law of m proportion, already described (p. 118), is a necessary quence of the *atomic theory*. The term *atom* is, accor frequently used in the same sense as the term *equiv* water may be described as consisting of one atom of gen, and one atom of oxygen, as well as of one equiva each of these elements. The numbers expressing th portions in which bodies combine, will also expre relative weights of atoms; these numbers, are, the often termed *atomic weights*.

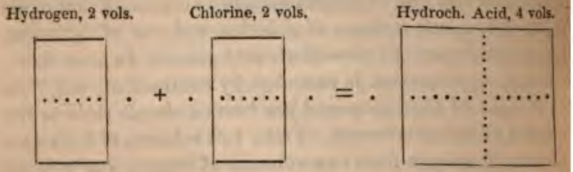
104. *Theory of Volumes.*—The proportions in which gaseous bodies combine can be determined by *measure*, as readily as by *weight*. All gaseous bodies combine by measure, or *volume*, in very simple and definite proportions. In other words, any volume or bulk of a gas always combines with an equal volume or bulk of another gas; or with a volume, bearing some simple relation to its own volume, as half of a volume, two volumes, &c., and not with any intervening fractional part of a volume. Water is always composed of *one* volume of oxygen, combined with *two* volumes of hydrogen. In this country, the two volumes of hydrogen are usually considered as *one atom*, or unity. Ammonia consists of *one* volume of nitrogen and *three* volumes of hydrogen gas.—1. When two gaseous bodies combine, and form a gaseous compound, this sometimes retains the original volume of its constituents, their combination being attended by no contraction or change of volume. Thus, one volume of nitrogen and one of oxygen form *two* volumes of deutoxide of nitrogen; one volume of chlorine and one of hydrogen form two volumes of hydrochloric acid gas.—2. In most cases, however, combination is attended by contraction, and then the volume of the compound gas bears a simple ratio to the volumes of its constituents. Thus, two volumes of hydrogen and one of oxygen form *two* volumes of steam; one volume of nitrogen and three of hydrogen form *two* volumes of ammoniacal gas; one volume of hydrogen and one-sixth of a volume of sulphur-vapour form *one* volume of sulphureted hydrogen gas. In all such cases, the gases compared are supposed to be in the same circumstances as to pressure and temperature.

105. A volume of a gas is usually represented by the figure of a *square*. The following are examples of this mode of expressing the combining measures of gases, and the products formed by their combination. In the first example, *three* volumes are condensed, by combination, into *two*; in the second, *four* volumes are condensed into *two*; in the third,

there is no condensation at all. The dotted lines represent *imaginary* divisions of the gases into volumes.







106. *Mode of ascertaining the Atomic Weights of Bodies.*— In bodies capable of assuming the gaseous form, the *atomi* *weight* can be easily obtained from the *volume*. Water, fo instance, consists of one volume of oxygen and two volume or one atom, of hydrogen ; the relative weights are, there fore, oxygen 8, hydrogen 1, and water 9.—In bodies i capable of assuming the gaseous form in their simple stat the atomic weight is deduced from that of the *compoun* the weight of carbon, for instance, is deduced from that carbonic acid gas, the compound which it forms with ox gen ; one volume of this gas weighs 22 times as much as t

andard two volumes, or one atom, of hydrogen; of these
2 parts, 16 are oxygen; the atomic weight of the carbon
, therefore, 6.—In bodies which are incapable of assum-
g the gaseous form, either in their simple or compound
ate, the atomic weight is obtained by analysis: common
arble, for instance, or carbonate of lime, consists of 22
arts of carbonic acid, and 28 of lime; the latter number,
herefore, expresses the atomic weight of lime.

107. *Classification of Compounds.*—Dalton observes,
When only one combination of two bodies can be obtained,
must be presumed to be a *binary* one, unless some cause
ppear to the contrary; and when two combinations are ob-
erved, they must be presumed to be a *binary* and a *ternary*.'
By a binary compound, is meant the combination of an
tom of each element; by a ternary, the combination of one
tom of one with two atoms of the other. If several com-
ounds can be procured from the same elements, Dalton
upposes them to combine in proportions expressed by some
imple multiple of the number of atoms, as in the following
able :—

1 of A + 1 of B = 1 of C, *binary*.
1 of A + 2 of B = 1 of D, *ternary*.
2 of A + 1 of B = 1 of E, *ternary*.
1 of A + 3 of B = 1 of F, *quaternary*.
3 of A + 1 of B = 1 of G, *quaternary*.

Berzelius proposed a different classification of atoms, viz.,
nto the *Elementary* and the *Compound*. The latter are
istinguished into *compound atoms of the first order*, or those
ormed by a combination of only two elementary substances;
rganic atoms, or those composed of more than two elemen-
ary substances, and named from their being found only in
rganic bodies, or bodies formed by the destruction of organic
natter; and *compound atoms of the second order*, or those
ormed by the union of two or more compound atoms, as the
alts.

108. *Isomeric Compounds.*—Certain substances have been discovered, in which the same elements have been found to exist in the same proportions, but in which the chemical properties are distinct from each other, owing to a difference in the arrangement of their particles. For these compounds, Berzelius has proposed the term *iso-meric* (from ἴσος, equal, and μέρος, part), denoting equality in their ingredients. Instances of this peculiarity occur in the two cyanic acids, and in the tartaric and para-tartaric acids; of the latter acids, the preposition, παρά, near to, is used to distinguish the one from the other. When the proportion of the elements of different compounds is the same, but the total number of each is greater in one compound than in the others, such compounds are called *poly-meric* (from πολὺς, many). Those compounds in which the ultimate elements are the same as in other well-known compounds, but which may be considered to present different arrangements, are termed *meta-meric* (from μετὰ, a preposition denoting *change)*.

V. CHEMICAL NOMENCLATURE.

109. There is no science in which a correct nomenclature is of more importance, than Chemistry. In former times, chemical substances received arbitrary names, without any reference to their composition. Thus, sulphuric acid was termed *oil of vitriol;* liquid ammonia, *bone spirit;* muriate of lime, *liquid shell* and *oil of lime.* Towards the close of the last century, considerable improvement was effected in this department, and the newly discovered elements were named from some characteristic property, as will be seen in the chapters on oxygen, hydrogen, chlorine, &c.

(1.) The terms *binary*, *ternary*, *quaternary*, &c., were applied to compounds, by Dalton, to denote the number of atoms of which they were composed. By Dr. Reid, these terms are employed to denote the number of elements or proximate principles in a compound, not the number of atoms.

(2.) Compounds of which oxygen forms a part, are called *cids* or *Oxides*, according as they do, or do not, possess cidity: oxygen and sulphur form a compound with *acid* roperties; oxygen and iron form an *oxide*, without acid roperties.

(3.) The term *Acidity* is applied to bodies which have he power of reddening the blue colours of vegetables; that f *Alkalinity* to bodies which turn vegetable blue colours to reen, and yellow colours to brownish red; the former bodies re termed *acids*, the latter *alkalies*. The presence of an cid or of an alkali in solution, may be therefore detected by means of vegetable *colouring matters;* these are termed *tests*, from their *testing* or distinguishing the chemical composition of bodies; or *re-agents*, from their *re-acting* upon the elements of bodies. 1. By means of an infusion of *red cabbage*, a blue colouring matter is obtained, which turns *red* by the action of acids, and *green* by the action of alkalies. The colouring matter of violets may be used for the same purpose. 2. *Litmus* is a blue colouring matter prepared from the *Lichen Rocella*. A slip of paper tinged with this substance, is more readily affected by *acids* than the colouring matter of cabbage, but is not turned to green by alkalies. But if previously reddened by acids, it becomes a valuable test for alkalies, which restore its blue tint. 3. *Turmeric* is a yellow colouring matter prepared from the *Curcuma longa*. A slip of paper stained with a decoction of this substance, detects the presence of *alkalies* by forming with them a brown compound. It is not affected by acids; but, if previously rendered brown by an alkali, it is a valuable test for acids, which restore its original yellow tint.

(4.) The names of the *Acids* are derived from the substances with which oxygen combines, and these substances are termed the *bases:* in sulphuric acid, sulphur is the base; in carbonic acid, carbon. A base may combine with oxygen in more proportions than one, and form acids of different degrees of strength; these proportions are indicated by a different termination of the name of the acid; that in which

SECTION II.

CHEMISTRY OF INORGANIC SUBSTAN

CHAPTER IV.

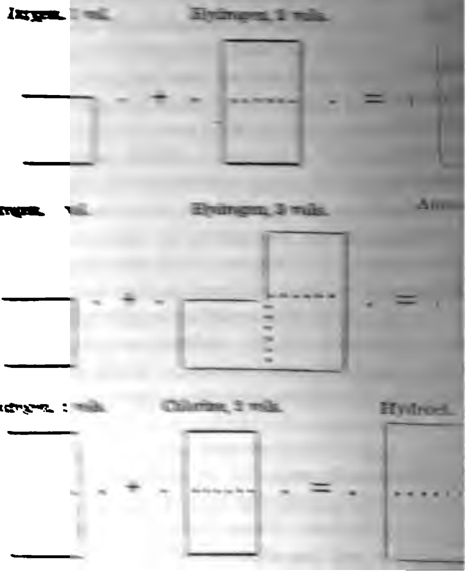
OF CHEMICAL ACTION.

§ 1. *General Remarks.*—The *physical* propertie have been already briefly noticed (p. 8). There are, other forces in nature, which belong more exclusiv science of Chemistry, and which, with reference to ments of which our globe is composed, produce eff in importance and interest to any other. 1. If mixed with water, or salt with salt, the effect is m increase of *quantity*; no change of *quality* is p 2. If a blue and a yellow powder be mixed together. powder is produced; but this is merely an effect i upon the eye by the intimate mixture of the yellow light which is separately reflected from the minute of each; these particles may be separated mechanic the powders restored to their former appearance two coloured liquids, having no chemical attraction other, be mixed together, a liquid of a different produced, and the two ingredients cannot, it is true, chanically separated; yet, even in this case, the li mere *mixture*, and its properties are accordingl mediate between those of the liquids mixed. In the cases there is *no change of property*, nor is any new nate, as in sub-borate of soda. A *double salt* is a compound of two salts, as the tartrate of potassa and soda, which is considered as consisting of tartrate of potassa and tartrate of soda. A *triple* salt denotes a compound of three salts. *Haloid* Salts, so named from ἅλς, salt, and εἶδος, form, are compounds of the metals with such bodies as chlorine, iodine, bromine, fluorine, and cyanogen; but the term does not apply to compounds containing oxygen and sulphur; they are similar in their constitution to common salt. *Sulpho-Salts* consist of compounds, both of which contain Sulphur. *Oxy-Salts* are compounds in which oxygen exists both in the acid and the base.

(9.) There are several terms employed to express *solution* of solid matters, as performed under various circumstances; these terms relate to cases in which the whole of the solid matter, placed in the liquid, is not dissolved, a portion of it only being extracted, and passing into the liquid state. When a substance to be subjected to the action of water has hot water merely poured upon it, this is called *infusion.* When heat is applied to the liquid for some time, this is called *decoction.* When cold or warm water is poured on the substance, and allowed to remain for some time, this is termed *maceration.* When a saline matter is extracted by means of water from a solid mass which consists of both soluble and insoluble ingredients, the process is termed *lixiviation.* When a substance is subjected for some time to the action of a solvent, it is said to undergo *digestion.* A liquid which acts the part of a solvent, without changing the nature of the substance to be dissolved, is termed a *menstruum.*

(10.) The vaporization and subsequent condensation of liquids constitute the process of *distillation.* The subjection of bodies to a red heat in close vessels, and the collection of the products, constitute *destructive distillation.* The process by which volatile substances are raised by heat, and again condensed into the solid form, is called *sublimation;* it is, in fact, dry distillation.

there is no condensation at all. The dotted
imaginary divisions of the gases into



[illegible] *Mode of ascertaining the Atomic Weights.*— In bodies capable of assuming the gaseous form, weight can be easily obtained from the volume. instance, consists of one volume of oxygen and or one atom, of hydrogen; the relative weights are, oxygen 8, hydrogen 1, and water 9.—In capable of assuming the gaseous form in their the atomic weight is deduced from that of the the weight of carbon, for instance, is deduced carbonic acid gas, the compound which it gen; one volume of this gas weighs 22 times as hydrogen. A figure prefixed multiplies the symbol: thus 2 H, 3 H, 4 H, denote two, three, and four equivalents, respectively. Two equivalents are sometimes denoted by placing a dash through, or under, the symbol: thus Ħ, or $\underline{\mathrm{H}}$, signifies the same as 2 H, or two equivalents.

(2.) *Compounds* are represented by placing the symbols of their elements together. Thus, S Fe denotes sulphuret of iron. Or the compound may be expressed by an algebraic formula, as $\mathrm{S} + \mathrm{Fe}$.

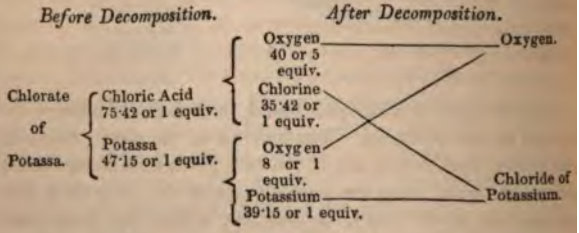
(3.) A dot ($\cdot$) *prefixed to*, or *placed over*, a symbol, indicates one equivalent of *oxygen*. Thus $\cdot\mathrm{H}$ or $\dot{\mathrm{H}}$ denotes one equivalent of oxygen and one of hydrogen, or $\mathrm{H} + \mathrm{O}$. Each additional dot denotes another equivalent: thus, $:\mathrm{C}$, or $\ddot{\mathrm{C}}$, denotes one equivalent of carbon and two of oxygen, or carbonic acid; $:\vdots\mathrm{N}$, or $\overset{\cdot\cdot}{\overset{\cdot\cdot\cdot}{\mathrm{N}}}$, denotes one of nitrogen and five of oxygen, or nitric acid.

(4.) A figure *prefixed to* any symbols multiplies all the following symbols which are not separated from it by a + sign. Thus $2\cdot\mathrm{H}\vdots\mathrm{S} = 2\cdot\mathrm{H} + 2\vdots\mathrm{S}$; in this case, the compounds $\cdot\mathrm{H}$ and $\vdots\mathrm{S}$ are both multiplied by 2. But in the following formula, $2\cdot\mathrm{H}\vdots\mathrm{S} + \cdot\mathrm{K} = 2\cdot\mathrm{H} + 2\vdots\mathrm{S} + \cdot\mathrm{K}$, the two first compounds only are multiplied by 2, the third being merely added.

(5.) A figure *placed after* any symbol multiplies that symbol, but does not affect any other symbol in the formula. Thus, $\mathrm{H}^2\mathrm{C} = 2\,\mathrm{H} + \mathrm{C}$; in this case, H is multiplied, while C is only added. In the formula, $\mathrm{N}\,\mathrm{H}^3 = \mathrm{N} + 3\,\mathrm{H}$, the latter symbol alone is multiplied.

(6.) In complicated combinations, *brackets* are often used to contain the symbols which are supposed to be united. Thus, in the formula $[2\,\mathrm{H}\,\mathrm{C}^2\,\mathrm{N} + \mathrm{C}^2\,\mathrm{N}\,\mathrm{Fe}] + 2\cdot\mathrm{K}$, there are two compounds; the former is composed of the symbols within the brackets, the latter consists of the symbols placed outside the brackets.

(7.) A figure *prefixed to any number of symbols enclosed within brackets*, multiplies them all, whether there are in-is fixed horizontally to both sides of the trough, and extends to half its breadth, so that there is a large open space on one side. The shelf is perforated with a few holes. When the trough is to be used, it must be filled with water to a little above the level of the shelf, which must always be completely covered with the liquid. When it is required to collect a gas, a jar or receiver must be filled with water, and inverted over one of the holes on the shelf. As most gases pass through water without mixing with it, and are lighter than water, they rise above its surface, and may be collected into a receiver, as shown in the figure. As the gas ascends, the water is forced down until it is all expelled, and the receiver is consequently filled with gas.) In this way the chlorate of potassa parts with all the oxygen it possessed, amounting to 37 per cent. of its weight; and a white hard salt, called chloride of potassium, is left in the flask. The *changes* which have taken place in this experiment, are the following: chlorate of potassa consists of chloric acid and potassa; of these, chloric acid consists of oxygen and chlorine, and potassa consists of oxygen and potassium. All the oxygen escapes, by the application of heat, and the chlorine of the chloric acid combines with the potassium of the potassa, forming chloride of potassium. The process may be illustrated by the following *diagram:*



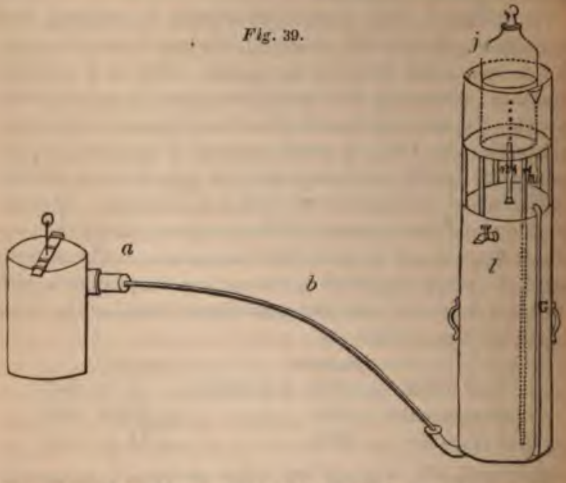
It appears, therefore, according to the *Atomic* composition of this salt, that one equivalent of it contains six equivalents of oxygen—five in the chloric acid, and one in may be seen on a window in frosty weather. 2. If a quantity of sugar be dissolved in water, and the solution be allowed to evaporate, the sugar again becomes solid; but, in resuming its solidity, it assumes a particular form of great regularity,—it is now a transparent six-sided prism. 3. If a wire basket be suspended in a strong solution of alum, or sulphate of copper, and withdrawn in an hour or two, it will be found to be covered with a crust of beautifully formed crystals. 4. If half an ounce of the sulphates of magnesia, of soda, of copper, and half an ounce of alum, be mixed together in boiling water, and allowed to evaporate, each salt will be found to crystallize separately, having the same form and properties which it possessed previously to its solution.

113. The *facility with which bodies crystallize*, varies considerably: some assume the crystalline form with great readiness, others only with great difficulty. Crystals are generally procured by the gradual change of a liquid into a solid, the cohesion of the particles being undisturbed by motion. There are two methods of this kind by which crystals may be obtained: the substance to be crystallized may be dissolved in as little boiling water as will suffice to hold it in solution, and the solution allowed to cool; or the substance may be melted by heat, without water, and then allowed to cool. The more slowly the liquid cools, the more regular will be the crystals. In some cases, the liquid must be reduced to the freezing point, before the crystals will form. In other cases, the water of a solution must be gradually boiled away, as in the process of crystallizing sea-salt.

114. The *tendency to crystallize is often very nicely balanced by very inconsiderable causes.*—1. If a quantity of Glauber's salt be dissolved in as small a quantity of hot water as will hold it in solution, and the solution be poured, while hot, into a glass vessel which just holds it, and which is tightly covered over with moist bladder, no crystallization will take place, even when the solution is cold, if the vessel have

the orifice, where the leaden tube enters; but as the gas rises in the cylinder, the water is forced out, as in the case of the inverted receiver. A glass gauge tube G is fixed from the upper to the lower part of the cylinder, and opens into the cylinder at both ends; the water, therefore, stands at the same height in the tube as in the cylinder, and its height in the tube affords a means of ascertaining the quantity of gas collected in the cylinder. When the lower cylinder is filled, the opening at which the gas was admitted, is closed. The upper cylinder is an open water-trough, connected with the lower cylinder by two tubes provided with stopcocks, *m* and *n*. One of these, *m*, is continued downward to the bottom of the lower cylinder, and conveys water from the upper to the lower cylinder. The other tube, *n*, terminates at one extremity in the top of the lower cylinder, and at the other admits a passage for the gas from the lower into the upper cylinder, through a perforation in the latter. A jar *j* may then be filled with gas, by inverting it, full of

Fig. 39.



useful in determining the physical character of salts. The same substance is frequently found to assume different forms. Hence, crystallographers have distinguished crystals into two kinds:—1, the *primary*, *derivative* or *fundamental* forms; and, 2, the *secondary* or *derived* forms. Thus, a cube is a *primary* form of crystal; but a cube with its angles, or its edges, planed off, is a *secondary* form; and these three forms may be replaced by each other in the *same* substance. The further consideration of the *forms* of crystals belongs to the subject of Crystallography.

117. *Isomorphous Bodies.*—It was discovered by Mitscherlich that some bodies crystallize in the same form, though totally different from each other in chemical properties; and that they may, therefore, be substituted for each other in combination without affecting the external character of the compound. Bodies of this kind are termed *Isomorphous* (from ἰσος equal, and μορφὴ form), and several groups of them have been described. The *law* at which Mitscherlich arrived is as follows: The same number of atoms, combined in the same way, produce the same crystalline form; and crystalline form is independent of the chemical nature of the atoms, and determined only by their number and relative position.

118. *Dimorphous Bodies.*—Some doubt has been thrown on the doctrine of Isomorphism, by the circumstance that some bodies, when treated in different ways, afford two varieties of crystals, the primary forms of which are incompatible with each other. Sulphur and carbon, for instance, have, each, *two* crystalline forms, which are incompatible with each other. Such bodies are termed *Dimorphous* (from δὶς, twice, and μορφὴ, form). No *tri*-morphous bodies have hitherto been discovered.

119. *Plesiomorphous Bodies.*—Another argument against the doctrine of Isomorphism has been founded on the circumstance that the forms of substances are *not exactly alike, but nearly so.* This approximate resemblance induced Professor Miller to designate such bodies as *plesio-*

morphous (from πλησίος, near, and μορφὴ, form). Turner observes that it is an important matter to ascertain the distinction between isomorphous and plesiomorphous bodies, and to discover if two substances may be *plesiomorphous* in one state of combination, and *isomorphous* in another.

RECAPITULATION.

81. What is the general difference between a *mechanical mixture* and a *chemical compound?*—83. Give some instances of *chemical affinity*, as exhibited between different bodies.—84. What is *single elective affinity?* Illustrate its operation in three substances. Describe a case in which its operation is attended by *decomposition.*—85. What is *double elective affinity?* Illustrate its operation in two compounds. State the composition of muriate of ammonia and of lime; and describe the *changes* which result from their chemical action upon each other.—86. Give some examples of *change of properties* as induced by chemical action.—87. Give some examples of *change of density*. In what instances is the density of bodies *increased* by chemical action?—88. Under what circumstances is *change of temperature* a result of chemical action?—89. How may bodies undergo a *change of form* by chemical action?—90. Give examples of *changes of colour, smell, taste, and sound*, as induced by chemical action.—91. Illustrate the antagonism which exists between *cohesion* and *affinity*.—92. How may it be inferred that cohesion determines the result of chemical action, even in opposition to affinity?—93. How does *elasticity* counteract the tendency of affinity? In what cases does elasticity act as a *decomposing* agent?—94. Explain the influence of *quantity of matter* in effecting decomposition—in forming solutions—in favouring chemical action.—95. How does *gravity* modify chemical action? Give some instances of its counteracting power.—96. What is meant by *specific*

and light; the latter body is called a *combustible*, and, instead of undergoing oxidation, is said to be *burned;* the oxygen which combines with it, and supports the burning of it, is called a *supporter of combustion.* This may be illustrated by the chemical process of the *burning of a candle or lamp.* The wick is lighted by a piece of burning paper or wood; by this means the particles of fat or oil immediately contiguous to the flame are heated sufficiently to be decomposed into inflammable *gaseous* matter; this combines with the oxygen of the surrounding air, and produces the phenomenon of *flame;* the flame gives out sufficient heat to decompose another portion of the fat or oil; and thus the process continues until the whole of the candle or oil is exhausted. On burning any combustible substance in a jar of oxygen, a considerable quantity of the gas disappears, while the weight of the combustible increases in exact proportion to the loss of the oxygen; a combination has thus taken place between the gas and the combustible, and an *acid* or an *oxide* is formed; this compound may be again resolved, by chemical action, into its constituent elements. The *amount* of heat emitted, during combustion, varies with the substances burned. It is, however, definite, and may be measured. The plan adopted is to melt ice, to raise water from the freezing to the boiling point, or to convert water into steam. The quantity of heat appears to be in proportion with the quantity of oxygen consumed: the greater the quantity of oxygen consumed, the more heat is developed. The following table shows the amount of heat evolved by burning four substances of variable quantity, with the same quantity of oxygen; the amount is nearly the same:—

		lbs. of Water.
1 lb. Oxygen	with Hydrogen heats from 32° to 212°	29½
,,	with Charcoal	29
,,	with Alcohol	28
,,	with Ether	28½

OF THE NON-METALLIC ELEMENTS.

CHAPTER V.

OF OXYGEN.

120. *General Remarks.*—Oxygen, in its *elementary* state, is a *gas*. It is one of the few elementary substances which occur naturally in the gaseous form; in this state, and uncombined, it constitutes about one-fifth of atmospheric air. In a state of *combination*, this element occurs in such vast abundance as to form upwards of one-half of the globe. Oxygen exists in the *liquid* form in water, in which it occurs in combination with hydrogen, in the proportion of one volume of the former to two volumes of the latter gas. Oxygen is found also in the *solid* state: most of the mineral bodies forming the crust of the earth, contain more or less oxygen; and it exists, as an elementary principle, in almost all the products of the animal and vegetable kingdoms. Oxygen is, perhaps, the most important of all the elements; from its proneness to enter into composition, it is constantly operating upon, and modifying, every thing in nature. The complicated apparatus, connected with the respiration of animals, is obviously constructed with reference to the properties of oxygen as it exists in the atmosphere. Oxygen was discovered in 1774 by Priestley, who called it *dephlogisticated air;* and soon afterwards by Scheele, who called it *empyreal air;* by Condorcet it was termed *vital air*. Its present name, Oxygen, is derived from οξὺς, acid, and γεννάω,

I generate, and was given to it by Lavoisier, with reference to its property of forming *acids* in combination with other elementary bodies. The subject of oxygen may be considered under the following heads:—

1. *Mode of procuring Oxygen.*
2. *Properties of Oxygen.*
3. *Theory of Combustion.*
4. *Uses of Oxygen.*

121. *Mode of procuring Oxygen.*—Oxygen gas is generally disengaged from some compound containing it, by the action of heat. A large quantity of perfectly pure oxygen may be obtained by the following process. Half an ounce of the salt called *chlorate of potassa* is placed in a Florence oil flask, furnished with a perforated cork, into which a bent glass tube is fixed, as shown in the figure. The flask is placed upon a chemical stand, and heat is applied by means of a spirit lamp. The salt melts, though it contains no water, and, when nearly red hot, gives off an abundance of oxygen gas. The gas passes through the glass tube, and enters the glass vessel, or *receiver*, which had been previously filled with water, and inverted upon the shelf of a pneumatic trough. (The *pneumatic trough* is a vessel made of tinned iron, and capable of holding a large quantity of water. At the depth of about two inches from the top, a shelf

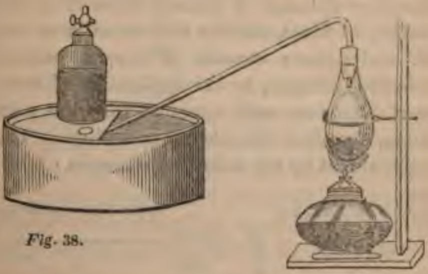


Fig. 38.

CHAPTER VI.

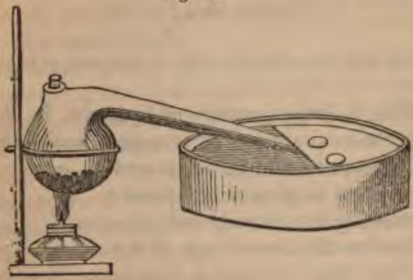
OF HYDROGEN.

130. *General Remarks.*—Hydrogen, in its *elementary* state, is a *gas*. It is, however, found in nature only in a *combined* state. It occurs most generally, and abundantly, in combination with oxygen, in the form of *water*, and it enters into the composition of almost every organic substance. In reference to organized beings, therefore, hydrogen ranks next in importance to oxygen. It differs from oxygen in not being, in its elementary state, necessary to life; indeed hydrogen is actually incompatible with the existence of animals, if not of vegetables; and its properties, as an element have evidently been sacrificed to its properties as a compound; that is, to its properties as a constituent of *wate* From the inflammable nature of Hydrogen, it was former called *inflammable air;* from its being considered the matt of heat, it was also called *phlogiston.* Its present name Hydrogen is derived from ὕδωρ, water, and γεννάω, I generat in reference to its forming *water* in combination with oxygen. The subject of Hydrogen may be considered under t following heads:—

1. *Mode of procuring Hydrogen.*
2. *Properties of Hydrogen.*
3. *Uses of Hydrogen.*
    - *Oxy-hydrogen Blow-pipe.*
4. *Compounds of Hydrogen with Oxygen.*
    1. *The Protoxide, or Water.*
    2. *The Peroxide, or Oxygenated Water.*

Mode of procuring Hydrogen. — Hydrogen is pro- by decomposing water by means of iron, zinc, or some metal. The following is the simplest mode of ob- this gas. A glass *retort* must be procured. The of this vessel is represented in the subjoined figure.

Fig. 40.



etort should be *tubulated;* that is, it must be fur- with a mouth at the upper part, to which a cork, or -tight stopper of ground glass, is fitted. A number of iron nails, or small pieces of zinc, are to be introduced tubulature; water is then poured in, in much greater ity than is sufficient to cover the metal; and to this ed about the same weight of sulphuric acid as that nails. Effervescence immediately commences, owing e extrication of hydrogen gas, which is expelled gh the *beak* of the retort, and received into a glass receiver, inverted, as in fig. 38, full of water, upon helf of the pneumatic trough. By adding more sul- c acid, when the effervescence becomes feeble, fresh ies of hydrogen may be procured, and any number of lasses may thus be filled with the gas. The first ns of the gas, being mixed with the common air of etort, and therefore impure, should be allowed to e. One ounce of zinc will cause the evolution of 615

2. On the other hand, the composition of water may be proved *analytically*, or by *resolving water into its elements.* This is effected by means of the Galvanic battery. The subjoined figure represents a glass vessel, with a perforation on each side furnished with a cork, through which are passed wires connected with the two poles of a Galvanic battery The vessel is partly filled with water. Two glass tubes A and B, both filled with water, are inverted in the vesse As the stream of electricity passes from P to N, the water undergoes *decomposition*, the oxygen rises in one of the glass tubes, the hydrogen in the other, the volume of the latter being *twice* as great as that of the former. By this experiment, the proportions in which these elements combine, by *volume*, may be exactly determined: they are *two volumes of hydrogen, and one of oxygen.* The same result is obtained by *synthetic* experiment: if one volume of oxygen be mixed with three hydrogen, and the mixture be exploded by the elec spark, one volume of hydrogen remains after the explosi if the explosion be made with two volumes of oxygen two of hydrogen, one volume of oxygen remains after explosion. The proportions in which these gases com by *weight*, is 1 of hydrogen to 8 of oxygen. It has b found, by careful experiments, that 100 parts of pure w consist of 11·1 of hydrogen and 88·9 of oxygen, whic the ratio of 1 to 8·009, or very nearly the proportion ab stated.

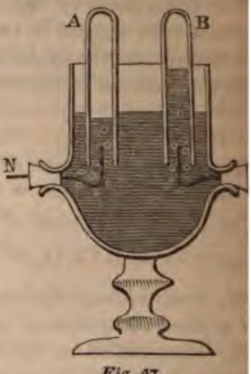


Fig. 47.

138. *Properties of Water.*—Water is a transpa liquid, without colour, smell, or taste. It is capabl existing in the *solid*, the *liquid*, or the *gaseous* form, acc

ed in it; when taken into the lungs in a large dose, it ces a shrill, squeaking sound of the voice. It has r acid nor alkaline properties. It is a non-conductor ctricity, and occupies the lowest position in the series gative electrics. It is sparingly absorbed by water, bic inches of this liquid dissolving about one and a f the gas. It is a powerful refractor of light. Its *lent by weight* is 1; its combining measure is *two es.* Its symbol is H.

) Hydrogen gas is the *lightest substance in nature.* 16 times lighter than oxygen, and 14·4 times lighter atmospheric air; 100 cubic inches of hydrogen gas only 2·14 grains. The *lightness* of hydrogen gas e exhibited in an amusing manner by the following iments. 1. A bell glass, furnished with a stop-cock, e filled with hydrogen by means of the water n, as represented at page 137; to this is fixed der, also provided with a stop-cock. On g both the stop-cocks, and lowering the r into the water, the gas is forced up into ladder, which may thus be filled, and re- l from the jar. A tube may then be adapted mouth of the bladder, and bubbles formed ping its extremity into soap lather; these bubbles pidly into the air, and may be fired by the application ne as they rise. If a little balloon of oiled silk be tuted for the bladder, it will rise into the air, owing low specific gravity of the gas. 2. If two bell-glasses ed with hydrogen gas, and placed, the one with its mouth upwards, the other with its mouth downwards, s will have entirely escaped from the former in a few es, but it will still be found in the latter. This may sily ascertained by applying the flame of a candle to outh of each glass; the contents of the latter only will

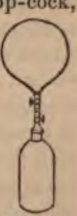


Fig. 42.

) Hydrogen is *highly combustible, but does not sup-* *ombustion.* In these respects hydrogen exhibits oppo-

containing oxygen. Thus, concentrated sulphuric
compound of one equivalent of the real acid and one
lent of water, and its proper name is *hydrous* su
acid, or *hydrate* of sulphuric acid. Water is also th
general of all solvents, its *solvent* power for most bod
creasing with its temperature. Thus, at 57°, water di
one-fourth of its weight of nitre, at 92° one-half, at 1
equal weight, and at 212° twice its weight of the salt.
lutions of such salts, saturated at a high temperature,
posit crystals on cooling (p. 131). Water is capable of
solving a certain quantity of air and gases, which ma
again expelled by boiling the water, or placing it in a vacu
The following table represents the quantities of differ
gases which are absorbed by water, which has been depriv
of all its air by ebullition. One hundred cubic inches
water in this condition, at the temperature of 60, and wi
the barometer at 30 inches, absorb of

	Dalton and Henry.		Saussure.
Sulphureted Hydrogen .	100	cubic inches	. 253
Carbonic Acid	100	,,	. 106
Nitrous Oxide	100	,,	. 76
Olefiant Gas	12·5	,,	. 15·3
Oxygen	3·7	,,	. 6·5
Carbonic Oxide	1·56	,,	. 6·2
Nitrogen	1·56	,,	. 4·1
Hydrogen	1·56	,,	. 4·6

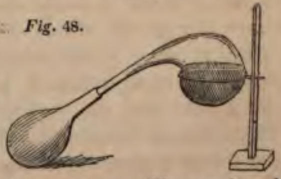
The results of Saussure are considered too high, except for sulphureted hydrogen and nitrous oxide, for which his estimate is more correct than that of Dalton and Henry.

141. *Uses of Water.*—Water, absolutely pure, does not exist in nature, being always charged in various degrees with air, or with animal, vegetable, or mineral substances. 1. *Rain-water*, collected at a distance from situations where it is exposed to dust or vapours, is the purest natural water; but even this is charged with impregnations from the air. 2. *Spring-water* generally contains earthy salts, and gases,

owing to its having flowed in contact with various rocks and minerals. 3. *River-water* is liable to the same impurities as spring-water. 4. *Well-water* is generally charged with foreign waters; the water of marshes contains vegetable matters in a state of putrefaction. 5. *Hard-water* owes its peculiar properties, generally, to earthy salts; these are, in some cases, precipitated by boiling; in other cases, the acid properties are neutralized by the addition of an alkali, as soda or potash. 6. *Chalybeate* waters are those containing iron; the metal frequently exists in the state of carbonate dissolved in carbonic acid, and it rarely occurs in a greater proportion than that of one grain to a pound of water. 7. *Sulphureous* waters contain sulphureted hydrogen gas, in a proportion not exceeding that of air in spring-water; and they contain no oxygen. 8. *Saline* waters usually contain salts of lime and magnesia, and generally common salt. 9. *Sea-water* contains 3½ per cent. of saline matter: that of the English Channel contains nine times as much lime as that of the Mediterranean; whilst the latter contains twice as much magnesia and sulphuric acid as the former.

142. Water, employed for *domestic* purposes, is freed from the impurities suspended in it, by the process of *filtration*. For this purpose, the water is allowed to percolate through filter paper, through strata of gravelly sand, or crushed cinders. Water, employed for *chemical* purposes, must previously undergo *distillation*. Distillation consists in separating some substance from another, by causing it to assume the form of vapour, and condensing the vapour in a separate vessel, the other substance being left behind. The apparatus employed for this purpose is represented in the annexed figure. The water to be purified is boiled in the *retort* for a little time in order to expel the gases; the beak of the retort is then introduced into the flask, called a *receiver*. The receiver is

Fig. 48.



kept cool by being placed in a vessel of cold water, or b allowing a stream of cold water to fall continually up it. The vapour arising from the boiling water is thus co densed, and returns to the liquid state, in the receiver: while the impurities of the water remain behind in the re tort. Distilled water which does not redden litmus pape nor give precipitates with muriate of baryta, nitrate of silve or oxalate of ammonia, may be considered fit for all ordina chemical purposes.

143. *Application of Steam as a moving power.*—T expansion of water into steam is employed as a movi power in the *Steam Engine.* The application of this age depends upon two principles, which may be illustrated by little instrument contrived by Wollaston. It consists of glass tube, which is enlarged at one end into a bulb, and is open at the other. A piston *p* is fitted to this tube, so as to move up and down with ease, but at the same time to be air-tight. Some water is put into the bulb, and heated; steam is formed, and the piston is raised to the top of the cylinder. In this case, *the elastic force of the steam* is the moving power, and this force is proportionably greater, as the piston is more loaded, and the steam more confined. If the bulb be now plunged into cold water, the steam in the cylinder is condensed, and a vacuum is produ below the piston, which is now forced down to the bott of the cylinder by the pressure of the atmosphere. In t case, the moving power is acquired by the *condensation the steam*, and the consequent production of a vacu This alternate motion may be repeated, and it constitu the source of power of the steam engine.

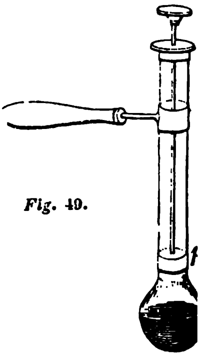


Fig. 49.

ept the passage of flame. (See *Safety Lamp*, ch. When the apparatus is made on a large scale, the kept in separate vessels, and are brought in con- at the tube from which they escape. Mr. Daniell osed an improvement on this principle, by which of oxygen is introduced *within* another stream of or of coal gas, so that the stream of oxygen is in the middle of the flame.

ompounds of Hydrogen with Oxygen.—Hydrogen with oxygen in two proportions. The compounds ned are the *protoxide*, or water; and the *peroxide.* mposition is as follows:

	By Weight.			*By Volume.*	
	Hydrogen.	Oxygen.		Hyd.	Oxy.
xide	1 or 1 equiv. +	8 or 1 equiv. =	9	100	50
ide	1 or 1 equiv. +	16 or 2 equiv. =	17	100	100

hemical symbol of water is H+O, or $\dot{H}$; that of ide is H+2 O, or $\ddot{H}$.

rotoxide of Hydrogen, or Water.—The sole pro- he combustion of hydrogen and oxygen, is *Water.* omposition of water may be proved *synthetically*, *formation* of water by the combination of these s. The simplest way of illustrating the formation is to invert a dry glass vessel over the flame of the *ical candle* (p. 151); as the combustion proceeds, piously deposited on the sides of the vessel, owing mbination of hydrogen with the oxygen of the air. *nation* of water may be also shown by ng the mixed gases into a strong thick glass *a*, furnished with a stopper *s*, n be pressed tightly down by means of and with a stop-cock *p*. By means of two *w*, which are inserted into the stopper, nunicate with the interior of the vessel, ric spark is passed directly through s, which combine with explosion, and deposited *upon* the sides of the glass.

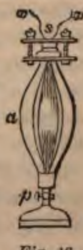


Fig. 46.

CHAPTER VII.

OF NITROGEN.

145. *General Remarks.*—Nitrogen, in its *elementar* state, is a *gas*. It is one of the very few elementary bodi which are found naturally in an uncombined state. T great bulk of this gas is confined to the *atmosphere*, of whi it constitutes about four-fifths, or 80 per cent., the rest bei principally oxygen. It forms a constituent element in anim and several vegetable substances, but enters very sparing into natural mineral productions. It is remarkably disti guished from other elementary bodies by the *absence* *active properties*. Notwithstanding the negative properti of nitrogen in its simple state, it forms most important a energetic compounds when made to combine with ot substances; some of these are atmospheric air, aqua fort ammonia, and prussic acid. The name *Nitrogen* was giv to this gas from its being an element in nitric acid; from being incapable of supporting respiration, it has been term *Azote*, or life-depriver. The subject may be studied in t following order:—

1. *Mode of preparing Nitrogen.*
2. *Properties of Nitrogen.*
    Atmospheric Air.
3. *Compounds of Nitrogen and Oxygen.*
    1. *Nitrous Oxide.*
    2. *Nitric Oxide.*
    3. *Hyponitrous Acid.*
    4. *Nitrous Acid (?)*
    5. *Nitric Acid.*

46. *Modes of procuring Nitrogen.*—Nitrogen is gene-
y procured from atmospheric air, every 100 parts of which
sist, by measure, of 79 of nitrogen and 21 of oxygen.

1.) When the air exhaled from the lungs of an animal has
n washed with lime water, which removes the carbonic
l, the gas which remains is found to be incapable of sup-
ting respiration. This is *impure* nitrogen gas.

2.) If a bell-glass containing atmospheric air be inverted
r a lighted taper, in a vessel containing a little water, as
wn in the adjoining figure, the flame becomes gradually
e dim, and is presently extinguished. The
ater part of the oxygen of the air is con-
ned in supporting the combustion of the
er; the remaining gas is principally nitro-
. The effect is rendered more striking, by
gradual rising of the water into the bell-
ss, in proportion as the oxygen is consumed.

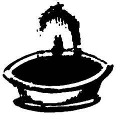
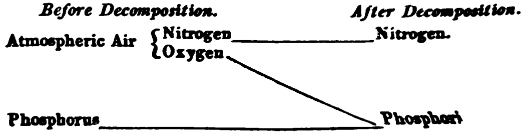


Fig. 38.

Instead of the taper, a paste made of iron filings and
phur be placed under the bell-glass, on a stand raised
ve the water, the oxygen of the contained air will be
dually diminished, and the water will ascend propor-
ably. The residue is principally nitrogen, as in the
ner case.

3.) If, instead of a lighted taper, a portion of phosphorus
burned under similar circumstances, the whole of the
gen will be consumed by the combustion. In this expe-
ent, the vessel becomes filled with white fumes, arising
n the combination of the phosphorus with the oxygen of
air; this substance is phosphoric acid. If the experiment
performed in a receiver over water in a pneumatic trough,
fumes are absorbed by the water, which rises propor-
nably in the receiver; and nitrogen gas *alone* remains.
ese *changes* are shown in the following *diagram*:—



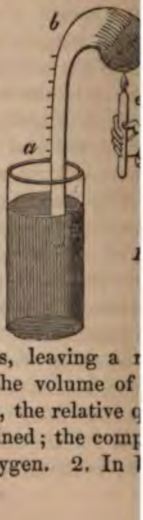
he elastic state, is inversely as the pressure to which it is ubjected. Thus, 100 volumes of air, under a pressure of ne pound, are reduced to 50 volumes under a pressure of wo pounds, and expand to 200 volumes under a pressure of nly half a pound.

149. The *pressure of the atmosphere* at the level of the sea s equal to a weight of about 15 pounds on every square inch of surface, and is capable of supporting a column of water of 34 feet in height, or a column of mercury of 30 inches. Thus, a column of air, the base of which is one inch square, reaching from the level of the sea to the limit of the atmosphere, a column of water of equal base and 34 feet high, and a column of mercury of equal base and 30 inches high, weigh each about 15 pounds. The pressure of the atmosphere *diminishes* with its elevation, the upper strata being always more rarefied and expanded than the lower strata upon which they press. Thus, at an elevation of 2·705 miles from the surface of the sea, the atmosphere loses half its density, or one volume is expanded into two, and the barometer would stand at 15 inches; the density is again halved for every 2·7 miles of additional elevation. The pressure of the atmosphere varies also in the same situation, as indicated by the barometer. The *causes* of these variations are not understood, but it is generally found that the weather is fair and calm when the mercury rises in the barometer, and wet and stormy when the mercury falls.

150. The *temperature of the atmosphere* varies with its levation. It is greatest at the surface of the earth, and liminishes one degree for every 352 feet of elevation, in he lower strata; at great distances, the progressive fall of emperature is less rapid. In the warmest climates, there s some point, at which the thermometer never rises above 32°; this point varies with the latitude, being highest within the tropics, and gradually descending in the direction of the poles. This diminution of temperature with elevation from the surface of the earth, appears to depend upon the joint influence of the *two following causes*. 1. The

atmosphere derives its heat, not from the rays of the su from the earth; its temperature is therefore lower further it is removed from this source of heat. 2. T creased rarity of the atmosphere in high elevations, is a panied by the production of cold, owing to its specifi being greater in a rarefied than in a more condensed (p. 60). The phenomena of *winds* (p. 22.) are occa by inequality of temperature of the atmosphere at dif points of the earth's surface.

151. *Analysis of Atmospheric Air.*—Various modes o *lysis* are practised in order to ascertain the quantity of gen or of oxygen contained in the atmosphere. This i constitutes the subject of *Eudiometry*, a term which d the *measuring of the quality* of the atmosphere. Fo purpose, substances are employed which will absorb o sume all the oxygen of a confined portion of air, care taken to employ a substance which will not mix w alter, the volume of the nitrogen. 1. In *Achard's E meter*, this effect is produced by the slow combusti *phosphorus*. A graduated glass tube *a b* is blown at one end into a bulb *c*, into which small pieces of phosphorus are introduced, in the proportion of one-third of a grain of phosphorus to one cubic inch of atmospheric air; the remainder of the tube is filled with mercury, and its open extremity is immersed in a jar filled with the same metal. The oxidation of the phosphorus is increased by heating the bulb by the flame of a candle. The oxygen of the atmospheric air in the tube unites with the phosphorus, leaving a of nitrogen; by comparing this with the volume of spheric air employed in the experiment, the relative q ties of the constituent gases are determined; the com always indicates 20 or 21 per cent. of oxygen. 2. In



eter, the effect is produced by the combination of one of oxygen with two volumes of hydro- form water. This instrument consists of graduated glass tube *a b*, closed at its y *a*, and open at *b*; two wires *c d* are to its sides, for the purpose of passing an spark through the contents of the tube. n of atmospheric air is carefully measured duated tube, and mixed with a quantity gen gas, which is rather more than suffi- r combining with all the oxygen present. The mix- ntroduced into the eudiometer, and an electric spark through it, the open extremity being closed by the t the moment of detonation, in order to prevent any ixture from escaping. Water is formed by the com- 1 of one volume of oxygen with two of hydrogen; one herefore, of the diminution of the mixed gases repre- e volume of oxygen in the atmospheric air employed.

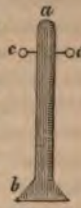


Fig. 52.

combustion of the mixed gases may be effected, explosion, by means of a little piece of spongy pla- introduced into a graduated tube placed over mer- In every case pure atmospheric air is found to be y constituted. But the atmosphere is never abso- ure; it always contains a variable quantity of watery carbonic acid gas, and other volatile and odoriferous , which, though inappreciable by the senses, can be d by chemical tests.

The properties of the atmosphere are much affected presence of *watery vapour* in it, which it acquires by with the surface of the ocean, rivers, lakes, and oil. The quantity which it can contain is limited by perature; and it is again condensed and precipitated, rious causes, in the form of dew, rain, &c. (p. 49.)

The presence of *carbonic acid* in the atmosphere is d by exposing to it a vessel of lime water, which is vered over by a film of carbonate of lime. Saussure carbonic acid in the air collected at the top of Mont

Blanc; and there can be no doubt of its being diffused through the whole mass of the atmosphere. The *mean* proportion of carbonic acid is 4·9 volumes in 10,000 volumes of air, or almost exactly 1 in 2000 volumes; but it is found to vary in the same place within short intervals of time; the variations range from 6·2 as a *maximum* to 3·7 as a *minimum* in 10,000 volumes of air. The proportion is greater in summer than in winter, greater during night than in day time, and greater in gloomy than in clear weather. It is also more abundant in elevated than in low situations; but in the former, its quantity is nearly the same by day and night, in wet and in dry weather; whereas in the latter, its quantity is diminished by the moist state of the ground, as after rain. The presence of carbonic acid in the atmosphere is essential to vegetable life; *plants* absorb this gas during the day, decompose it within their tissues, and appropriate the carbon for their support, while they evolve the oxygen with which it was combined. During night opposite effects are produced: oxygen is absorbed, and carbonic acid evolved. But it has been shown that plants, during twenty-four hours, yield more oxygen than they consume.

154. The constitution of the atmosphere, above described, affords an instance of the *beneficial adjustments* of nature. On this subject, Dr. Donovan observes:—'Were the atmosphere to consist wholly of *oxygen*, and the different kinds of objects which compose, and are found upon, the globe, to remain what they are, the world would run through its stages of decay, renovation, and final destruction, in a rapid cycle. Combustion, once excited, would proceed with ungovernable violence; the globe, during its short existence, would be in a continual conflagration, until its ashes would be its only remains; animals would live with hundred-fold intensity, and terminate their mortal career in a few hours. On the other hand, were the atmosphere wholly composed of *nitrogen*, life could never have existed, whether animal or vegetable, and the objects of the Creator in forming this

world would not be fulfilled. But the atmosphere is a wholesome *mixture* of these two formidable elements, each neutralizing the other's baneful influence. The life of animals runs quietly through its allotted space; and the current of nature flows within prescribed limits, manageably and moderately.'

155. *Compounds of Nitrogen and Oxygen.*—The compounds of Nitrogen and Oxygen are five; of these, two are oxides, and three acids. They afford striking instances of the direct proportions in which gases combine with each other by *volume*. Their composition and equivalents, as stated by Turner, are as follow:—

	By Volume.		*By Weight.*		
	Nitr.	Oxyg.	Nitr.	Oxyg.	Equiv.
Nitrous oxide . .	100 .	50	14·15 +	8 =	22·15
Nitric oxide . . .	100 .	100	14·15 +	16 =	30·15
Hyponitrous acid .	100 .	150	14·15 +	24 =	38·15
Nitrous acid . .	100 .	200	14·15 +	32 =	46·15
Nitric acid . . .	100 .	250	14·15 +	40 =	54·15

156. *Nitrous Oxide, or Protoxide of Nitrogen.*—Nitrous oxide is procured by decomposing *nitrate of ammonia*. A few ounces of this salt are to be introduced into a retort, and heat gradually applied by means of a pan of charcoal, the diffused heat of which is more convenient in this preparation than that of a lamp. The salt melts, boils at a temperature of about 480°, and is decomposed; the results of the decomposition are water and nitrous oxide gas, the latter of which may be collected in a gas-holder, as described at page 139. The nature of this process may be readily understood by the following *diagram*, copied from Prof. Graham's Chemistry, in which 1004 parts, or 1 equivalent, of the nitrate of ammonia are employed. It will be observed that three equivalents of hydrogen in the ammonia combine with three equivalents of oxygen in the nitric acid, and form water; while the two equivalents of nitrogen in the ammonia

[illegible]

[illegible] *atmospheres* [illegible] [illegible] liquid, which [illegible] again [illegible] the pressure. Nitrous oxide is [illegible] a candle burns [illegible] less

[illegible] *atmospheres* are spoken of, the term signifies [illegible] arising from condensation, the ordinary [illegible] on the square inch. *Atmospheric* [illegible] length of a column of mercury. A mer- [illegible] length, presses on a given surface with [illegible] here in its ordinary state; and hence, [illegible] a pressure of two atmospheres, 15 [illegible] and 1 inch to 1-30th of the atmospheric

ancy than in oxygen, but with greater than in common
phosphorus, sulphur, and charcoal, require to be well
ed before they are immersed in this gas; an iron wire
in it, but for a shorter time than in oxygen. With
ual bulk of hydrogen, it forms a mixture which ex-
s violently by flame or the electric spark; the hydro-
combines with the oxygen, and nitrogen is liberated.
most remarkable property of this gas is its effect on
l life, when breathed. Davy discovered that it sup-
respiration for a few minutes. He thus described the
s produced on himself by inhaling this gas. 'Having
ously closed my nostrils, and exhausted my lungs, I
hed four quarts of nitrous oxide from and into a silk
The first feelings were those of giddiness; but in less
half a minute, the respiration being continued, they
ished gradually, and were succeeded by a sensation
gous to gentle pressure on all the muscles, attended by
ly pleasurable thrilling, particularly in the chest and
tremities. The objects around me became dazzling,
y hearing more acute. Towards the last inspiration
rilling increased, the sense of muscular power became
er, and at last an irresistible propensity to action was
ged in. I recollect but indistinctly what followed: I
that my motions were various and violent. These
s very soon ceased after respiration. In ten minutes I
ecovered my natural state of mind. The thrilling in
tremities continued longer than the other sensations.
gas has been breathed by a very great number of per-
and almost every one has observed the same things.
ome few, indeed, it has no effect whatever, and on
the effects are always painful.' Davy breathed nine
of this gas for three minutes, and twelve quarts for
more than four minutes, but was unable to continue
periment for a longer period.

. *Nitric Oxide, or Deutoxide of Nitrogen.*—Nitric
is procured by the action of nitric acid on metallic
r. For this purpose, some copper wire or sheet copper,

and [illegible]
of the [illegible]

F[illegible]

1004 Ni[illegible]
Au[illegible]

1004

Fro[illegible]
of am[illegible]
of wat[illegible]
cubic [illegible]
157[illegible]
colour[illegible]
odour[illegible]
sure,[illegible]
sure,[illegible]
(p. 1[illegible]
Its sp[illegible]
nearly[illegible]
Unde[illegible]
into [illegible]
with [illegible]
a sup[illegible]

* W[illegible]
multip[illegible]
pressu[illegible]
pressu[illegible]
curial[illegible]
the sa[illegible]
a 60-in[illegible]
inches to[illegible]
pressure.[illegible]

s that nitric oxide is an irrespirable gas, and that any
tempt to inhale it would be dangerous, as it would com-
ne with the atmospheric air in the lungs, and form nitrous
id vapours, which are extremely irritating and corrosive.

160. *Hyponitrous Acid.*— This acid is named from its
ntaining *less* oxygen than nitrous acid (ὑπό, under). It
the *Nitrous Acid of commerce.* It is formed by mixing
ur volumes of nitric oxide with one volume of oxygen,
th perfectly dry. The gases unite, and are *condensed*, at
temperature of 0° F., into a green-coloured liquid, which
so exceedingly volatile, as to pass off, in open vessels, in
e form of *orange vapours*, said to have a specific gravity
1·72. Hyponitrous acid does not combine directly with
alies and earths, being resolved, by these means, into
ric oxide and nitric acid; by heating the nitr*ates* of these
dies, however, to a gentle red heat, corresponding hypo-
rites may be procured (p. 126, § 5). Hyponitrous acid
capable of combining with several acids; thus, with sul-
uric acid and water, it forms a crystalline compound
ich is generated in large quantity in the preparation of
lphuric acid. Hyponitrous acid has a powerful affinity
water; this liquid changes its colour to orange, yellow,
green, according to the proportions used; much water
solves it into nitric oxide, which escapes with efferves-
nce, and nitric acid.

161. *Nitrous Acid* (?).—This compound consists of the
incipal part of the *orange vapours*, above mentioned,
ich always appear when nitric oxide is mixed with the
. Prof. Graham observes that, as this compound cannot
made to unite either directly or indirectly with bases,
d has no acid properties, any designation which implies
idity should be avoided, particularly that of *nitrous acid*,
ich is applied on the continent to the preceding com-
und. He adds that the name *peroxide of nitrogen* is more
accordance with the rules generally followed in naming
ch compounds. This compound may be procured in the
seous, and in the liquid, form. 1. The *gaseous* peroxide

and it should therefore be preserved in a covered bottle. When suddenly mixed with 3-4ths of its weight of water, its temperature may rise from 60° to 140°. The *nitric acid of commerce* has an orange-coloured tint, owing to the presence of nitrous acid fumes which are disengaged during the process of preparing it.

(1.) Nitric acid is exceedingly *corrosive*, and acts with great energy on substances which are disposed to combine with oxygen; hence, it is much employed as an *oxidizing agent*. Nearly all the metals are oxidized by it; and some of them, as mercury, copper, zinc, and tin, with great violence. When poured upon burning charcoal, the brilliancy of the combustion is considerably increased. Sulphur, phosphorus, and iodine, are converted into acids by its action. When mixed with a fourth of its bulk of oil of vitriol, and thrown upon a few drops of oil of turpentine, an explosive combustion of the oil takes place. All vegetable substances are decomposed by it: its oxygen combines with the hydrogen and carbon of these substances, forming water with the one, and carbonic acid with the other. Animal substances are also decomposed by nitric acid; it stains the skin and nails of a yellow colour, and acts upon the former as a powerfu cautery. The orange patterns upon woollen table covers are produced by this agent. The strongest nitric acid, however, produces no violent action upon certain organic substances as woody fibre and starch, for a short time, but combine with them and forms remarkable compounds.

(2.) Nitric acid forms an important class of salts, calle *nitrates*. All of these are soluble in water; hence it is impossible to detect the presence of nitric acid in a solution b precipitating it in combination with any base. Its presence when uncombined, may, however, be detected by other *tests* thus, with copper and mercury, ruddy *fumes* of nitrous aci are emitted; with potassa, a neutral salt is formed, wit the properties of nitre; and, with a drop of hydrochloric aci added to the solution of a nitrate, the property of *dissolvin gold* is acquired, which free nitric acid does not possess.

.) Nitric acid is employed as the *solvent of metals.* It metimes used for *fumigation* in cases of contagious dis- ; for this purpose, pounded nitre and strong sulphuric are heated together in a cup ; the fumes are less irri- g than those of chlorine gas.

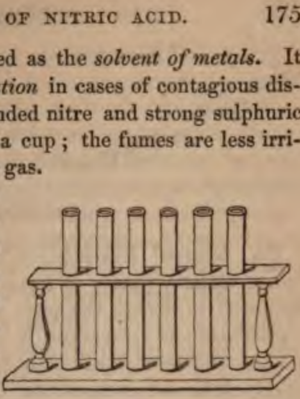


Fig. 53.

n operating upon very l quantities of mat- *test tubes* are employed etecting the ingredients compound. Several of should be constantly in iness, clean, and sup- ed in a stand, as shown e figure. In applying a several appearances may resented: *effervescence* may be produced, and the extri- d gas may be examined as to its inflammability, odour, ; or a *precipitate* may be thrown down, and this may tudied with reference to its colour, the rapidity with h it sinks, its solubility in other re-agents, &c. ; or there be simply a *change of colour*.

RECAPITULATION.

45. What is nitrogen ?—146. How may nitrogen be pro- ed ?—147. What are its properties ?—148. What is the position of *atmospheric air ?*—149. What is the *weight* he atmosphere ? How may it be measured ? How does ary with *elevation* from the earth's surface ?—150. Upon t causes does the *temperature* of the atmosphere depend ? 51. Describe the modes of *analyzing* atmospheric air.— . What proportion of carbonic acid does the atmosphere tain ?—157. What is the most remarkable property of *ous oxide ?*—162. Describe the process of procuring *nitric l.*—163. What are its chief properties ? What are the nomena produced by *testing* on the small scale.

CHAPTER VIII.

OF CARBON.

164. *General Remarks.*—Carbon is a substance which occurs under a variety of forms. By chemists, the term is employed to denote the pure matter of *charcoal*. In its crystallized and pure state, it constitutes the *diamond*—the hardest and most brilliant body in nature. It enters very largely into the composition of vegetable substances, of which it may be considered, more perhaps than any other principle, the fundamental element. It is found abundantly in animal bodies, in which its effects are considerably modified by the presence of nitrogen. It occurs also in great quantities in the mineral kingdom, in which, in a nearly pure state, it forms the basis of *coal*. But it is found in still greater proportion in combination with oxygen, in the form of *carbonic acid*, which, combined with lime, constitutes *chalk* and *lime-stone*, two of the most abundant minerals in nature. A small portion of it, in the form of carbonic acid, enters into the composition of atmospheric air (p. 165.) Carbon, in its elementary state, is an *inert* substance; but with oxygen and hydrogen, it forms gaseous compounds of great energy, and of most deleterious properties. The subject may be studied under the following heads:—

I. VARIOUS FORMS OF CARBON.

1. *Diamond.*
2. *Graphite.*
3. *Wood Charcoal.*
4. *Animal Charcoal.*
5. *Coke.*
6. *Lamp-black.*
7. *Gas-Carbon.*

II. COMPOUNDS OF CARBON WITH OXYGEN.

1. *Carbonic Acid.*
2. *Carbonic Oxide.*

VARIOUS FORMS OF CARBON.

165. The variety of forms under which carbon is found,
rds a striking example of the effects which may be pro-
ced by different associations of particles of the *same* kind
matter. 'In order to give some idea of the proportion
which carbon exists in different common substances, it
y be observed, that a pound of charcoal is equal to, and
contained in rather more than, two pounds of sugar or
ur, and eight of potatoes or limestone; so that a moun-
n of limestone contains the essential element of, at least,
equal bulk of potatoes, and of a forest which would
ply cover many such mountains.' (*Prout's Bridgewater
eatise.*) The principal forms under which carbon exists
diamond, graphite, vegetable and animal charcoal, coke,
p-black, and gas-carbon.

66. *Diamond.*—The diamond is a *gem* of crystalline
ture; its primary form is the octohedron. Lavoisier
t proved the diamond to contain carbon, by concentrating
sun's rays upon it, by means of a powerful lens, in a
sel of oxygen gas; the diamond was entirely consumed,
gen disappeared, and carbonic acid was formed. It has
n since proved, by numerous experiments, that the dia-
nd is pure carbon, that charcoal is an oxide of carbon,
l that the product of the combustion of the diamond is
ntical with that derived from different kinds of charcoal.
close vessels, the diamond undergoes no change from the
st intense heat; but, when heated to redness in the open
, to about the melting point of silver, it is entirely con-
ned. It is not acted upon by acids or alkalies. It is a
-conductor of electricity. Its specific gravity is 3·520.
e diamond affords an instance of the intrinsic worthless-
s of an object upon which the highest value is set. The
ebrated Regent Diamond, originally purchased by Mr.
t for £20,400, and afterwards placed in the hilt of Napo-
n's sword, is now said to be valued at £260,000. Yet

led, as in the process of making coal-gas. It is very dens in its structure, and resembles charcoal made from wood. It affords great heat by combustion.

171. *Lamp-Black.*—Lamp-black is the soot deposited from oil, resin, and other compounds containing carbon, when they are imperfectly consumed. A very pure charcoal may be prepared from starch or sugar, and from the oil of turpentine or spirit of wine, by passing their vapour through porcelain tubes heated to redness. This variety of charcoal has not the attraction for organic matters which ordinary charcoal possesses.

172. *Gas-Carbon.*—Gas-Carbon resembles graphite, and is produced by deposition of carbon from coal-gas at a high temperature. Gas retorts are frequently found lined with this matter to a considerable thickness.

COMPOUNDS OF CARBON WITH OXYGEN.

173. Carbon surpasses all bodies in its affinity for oxygen at a high temperature. These elements combine, and form an *acid* and an *oxide*, in the following proportions o each :—

	Carbon.		Oxygen.		Equiv.
Carbonic oxide .	6·12 or 1 equiv.	+	8 or 1 equiv.	=	14·12
Carbonic acid .	6·12 or 1 equiv.	+	16 or 2 equiv.	=	22·12

174. *Carbonic Acid.*—Carbonic acid was first describe by Dr. Black under the name of *fixed air*. He discovere it in limestone and magnesia, and found that it could b separated from these substances by heat or the action acids. He also observed, that the same gas is formed durin respiration, fermentation, and combustion. The air of ordinary expiration contains, on an average, 3·45 per cen of carbonic acid, and the proportion varies from 3·3 to 4 per cent., being greatest at noon, and least during the nigh Carbonic acid is also a product of the vinous fermentatio imparting an agreeable pungency to fermented liquors, whi

me *stale* when deprived of it by exposure to the air.
combustion of carbonaceous fuel is attended with the
uction of vast quantities of this gas. Carbonic acid is
contained in the earth, and is discharged from volcanoes
fissures in their neighbourhood. It issues directly from
earth in the *Grotto del Cane* in Italy, and at Pyrmont in
tphalia. This gas accumulates at the bottom of wells,
ing a noxious and fatal atmosphere, called by miners
e damp. Many mineral springs, as those of Tunbridge,
mont, and Carlsbad, are strongly charged with carbonic
. In combination with lime, it forms extensive masses
ocks, occurring in all countries, and in every geological
ation. It is always present, though in a small quantity,
he atmosphere, at every elevation above the level of the
(p. 165). Carbonic acid is also a product of many natural
ations, as of the germination and vegetation of plants.
m these and other sources, carbonic acid is continually
ing around us in vast quantities; but by some com-
sating means it disappears as fast as it is formed; and
atmosphere, which, without this adjustment, would soon
me impregnated with carbonic acid to a fatal extent,
ly contains traces of it.

75. *Mode of procuring Carbonic Acid.*—There are se-
l ways of procuring carbonic acid.—1. If charcoal be
ned in oxygen gas, intense heat and light are produced,
carbon unites with the oxygen, and carbonic acid gas is
ned. In the combustion of pure carbon, as of the dia-
nd, the oxygen undergoes no change of volume: carbonic
gas contains, therefore, its own volume of oxygen.—
A more convenient mode of procuring the acid is to pour
n some carbonate of lime, as common *limestone*, *marble*,
halk, an acid which has a greater affinity for the lime
n the carbonic acid possesses. Hydrochloric acid, diluted
n two or three times its weight of water, takes the lime
n the carbonic acid, which escapes with effervescence,
may be collected by means of the pneumatic trough, in
manner already described (p. 137). The gas cannot be

long retained over water, owing to its solubility in this liquid; it should, therefore, be collected over mercury.

176. *Properties of Carbonic Acid.*—Carbonic acid is an elastic *gas* without colour or scent. Its specific gravity is estimated at 1524·1; its combining measure is 2 volumes. Cold water absorbs rather more than an equal volume of this gas. Water and other liquids may be charged with a much greater quantity by mechanical pressure; the quantity of the gas absorbed is in exact proportion to the compressing force: water absorbs twice its volume when the pressure is doubled, and three times its volume when the pressure is trebled. On removing the pressure, as when a bottle containing any aerated liquid is uncorked, the carbonic acid gas escapes with effervescence. It is to the presence of this gas that the agreeable acidulous taste of ginger beer, champagne, soda and other aerated waters, is owing. Water, when fully saturated with this gas, sparkles as it is poured from one vessel into another. The solution communicates to litmus paper a red stain, which disappears on exposure to the air. On adding lime-water to the solution, a cloudy precipitate is formed, which is again dissolved by the carbonic acid; but on adding lime-water, till the whole of the free acid is neutralized, a permanent precipitate is formed of carbonate of lime. The whole of the carbonic acid in a solution of water is expelled by boiling. Boiled water becomes insipid, owing to the absence of the carbonic acid and other gases, which had been absorbed by it from the atmosphere.

177. Carbonic acid *does not support combustion:* it extinguishes the flame of all burning bodies. A lighted taper, introduced into a jar of this gas, is immediately extinguished. The gas is so heavy, that it may be poured, like a liquid, upon a lighted taper, with the same effect of extinguishing it. The check upon combustion, produced by carbonic acid, is not owing to the mere absence of oxygen; for a candle will not burn in a mixture of four measures of atmospheric air and one of carbonic acid. Carbonic acid is *incombustible,*

d cannot be made to unite with an additional portion of ygen. It is a compound, therefore, in which carbon is in highest degree of oxidation.

178. Carbonic acid is *irrespirable:* it is fatal to animal e, when inspired. No animal can live in an atmosphere hich contains sufficient carbonic acid to extinguish a ghted candle; hence, it is a usual practice to lower a urning taper into a well or pit, before descending into it; the taper continue to burn, no danger is apprehended. n the *Grotto del Cane*, the gas exhaled from the ground ccupies the lowest stratum of about 18 inches, while the pper portions of the air are pure; for the instruction of trangers, a dog and a man are introduced into the cave; he dog dies, the man is unaffected. But the incautious nhalation of the vapours of charcoal in close apartments, nd in the large vessels of breweries and distilleries, has fforded numerous examples of the fatal effects of carbonic cid upon man. It acts upon the animal system like a narotic poison. Carbonic acid may exist in the atmosphere in ufficient quantity to produce insensibility, without being ufficient to extinguish flame.

179. The presence of carbonic acid is *tested* by means of *ime-water*. The lime combines with the acid, forming carbonate of lime, which renders the solution turbid, and forms a white flaky precipitate. Lime-water is frequently employed to remove carbonic acid from gaseous mixtures which contain it.

180. Carbonic acid gas has been condensed into a limpid colourless *liquid*, under a pressure of thirty-six atmospheres (p. 168, note) at 32° F. Thilorier lately discovered that at —148° F., carbonic acid becomes *solid*, and remains in this condition for some minutes, even when exposed to the air, without compression. Its elasticity, which in a liquid state is so great as to produce an explosion equal to that of the same weight of gunpowder, is destroyed by solidification, and the new solid is gradually dissipated by evaporation. Another curious fact is, that this gas is *solidified by* its suddenly passing from the liquid to the gaseous state; the near

approach of its molecules, which renders it solid, being caused by the expansion of a liquid which occupies instantaneously a space four hundred times greater than its original volume. If a jet of liquid carbonic acid be directed into a small glass vial, this becomes rapidly and almost entirely filled with a white flocculent powdery substance, which adheres so strongly to the glass that it cannot be removed without breaking the bottle. A fragment of solid carbonic acid, slightly touched by the finger, glides rapidly over a polished surface, as if it were raised by the gaseous atmosphere which constantly surrounds it, until it entirely disappears. If a small quantity of this substance be introduced into a small flask, hermetically stopped, the interior becomes filled with a thick vapour, and the stopper is violently expelled. Solid carbonic acid is completely evaporated, and only rarely a slight humidity remains, which must be attributed to the action of the air on a very cold body, of which the temperature is below that at which mercury freezes. Its abundance and the promptitude with which it is produced in cavities where neither air nor watery vapour, held in it, can penetrate, are characters which cannot be mistaken.—*Gazette Méd.* No. 43.

181. *Woolfe's Apparatus.*—It is sometimes desirable to impregnate water, for medicinal purposes, with carbonic acid. A saturated solution of this gas may be made by transmitting a stream of it through a vessel of cold water during the space of half an hour. This operation may be conveniently performed by means of what is called *Woolfe's Apparatus*. This, in its simplest form, consists of three bottles, mounted, with tubes, as represented in the figure, in a mahogany tray. The bottles are half filled with water. The vapour from a receiver or a retort is conveyed into the first bottle; that portion of it which is not condensed in the water of this

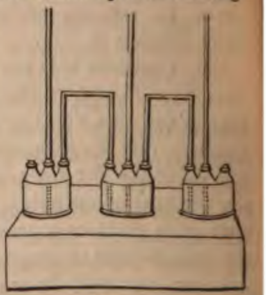
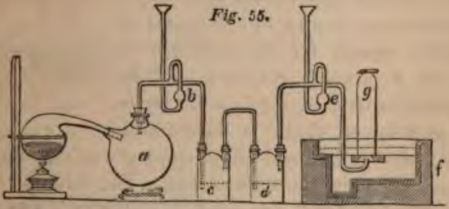


Fig. 54.

tle, passes on by the bent tube into the second; and m this, if required, into the third; the portion of gas ich is not absorbed by the last, is conveyed by a curved e into an inverted jar placed in a pneumatic trough, as in following figure. Besides the bent tube, each bottle is vided with a *safety tube*, the lower extremity of which ns beneath the surface of the water, while the upper nmunicates with the atmosphere. The object of this tube to prevent the fluid being forced backward into the rever or retort by pressure of the atmosphere, in cases of den absorption; for it frequently happens in chemical cesses, from the irregularity of the heat, or other circumces, that the condensation is more rapid in proportion to supply of vapour at some period of the operation than at rs. In such cases, air is supplied by means of the ty tube. Instead of this, a curved *Welter's tube* is now rally employed, as more convenient. In the subjoined re, which represents a useful modification of this appas, *a* is the receiver placed on a wreath of straw; *c*, *d*,

Fig. 55.



of Woolfe's bottles; *g* a jar inverted in a mercurial gh *f*. Each bottle is furnished with a Welter's tube. these tubes water is poured, till the balls *b*, *e*, are half When absorption takes place, the water rises in the till none remains in the tube, and then the air rushes On the other hand, no gas can escape, as it has to come the pressure of a high column of water in the endicular tube. In this apparatus, the vapour is condensed in the receiver, and the gas passes on into bottles; the portion of gas which is not absorbed or condensed at its exit from the last bottle, is conv the jar standing in the mercurial trough.

182. *Nooth's Apparatus.*—Another apparatus, of which water may be impregnated with carbonic that contrived by Dr. Nooth. It consists of three sels, as represented in the figure. 1. The lowes has an opening at *b*, which is furnished with a ground stopper. 2. The middle vessel B is open at both ends; the lower end is fitted by grinding to the neck of A, and is furnished with a valve at *a*, so constructed that it admits the *ascent of gas* from A, but prevents the *descent of liquid* from B; this middle vessel is also provided with a stop-cock D, by which its contents may be drawn off. 3. The uppermost vessel C is fitted by grinding into the upper neck of the middle vessel; its lower part is lengthened into a tube which passes almost as low as to the centre of the middle vessel; its upper orifice is closed by a ground stopper. When this apparatus is to be used, some powdered marble or chalk is introduced into the lowest vessel, and dilute sulphuric acid pc the opening, which is then closed. The middl filled with pure water, and fixed in its place. T most vessel is stopped, and also fixed in its plac vescence takes place in the lowest vessel, from gagement of carbonic acid. This gas passes tl valve at *a*, ascends into the upper part of the mid and forces part of the water up the tube into the vessel. In this vessel, the air is compressed, escapes by the stopper, which, being of a conic easily raised. As more carbonic acid is gener

Fi

vater rises, till at length the water in the middle vessel falls elow the lower orifice of the tube. The gas then passes hrough this tube into the uppermost vessel, and expels nore of the common air by raising the stopper. By this neans, the water in both vessels, being in contact with a ody of carbonic acid, becomes strongly impregnated with his gas after a certain time. This effect may be hastened, y taking off the middle and uppermost vessels together, nd agitating their contents. The impregnated water may hen be drawn off by means of the stop-cock.

183. *Carbonic Oxide.*—It has been stated that carbonic cid gas consists of two equivalents of oxygen and one of arbon. If a stream of this gas be transmitted over fragents of red-hot charcoal contained in an iron or porcelain ube, one equivalent of the oxygen is liberated, and the emainder is a compound of one equivalent of oxygen and ne of carbon. This is *carbonic oxide*. It may be procured y various other substances, which deprive carbonic acid, at red heat, of *half* of its oxygen. Thus, if two parts of ell-dried *chalk*, a compound of carbonic acid and lime, and ne of pure iron filings, be mixed together, and exposed in a un-barrel to a red heat, a quantity of gaseous matter is volved, which may be collected over water. This matter onsists of carbonic acid and carbonic oxide; by washing he mixed gases with lime-water, the acid is absorbed, and he *oxide* is left in a state of purity. In this operation, the arbonic acid of the chalk is converted into carbonic oxide y yielding oxygen to the iron filings, which thus become an xide of iron.

184. *Properties of Carbonic Oxide.*—Carbonic oxide is a olourless *gas*. It possesses no acid properties; nor does it ombine, like carbonic acid, with the alkalies. It is not nore soluble in water than atmospheric air, nor has it ever een liquefied. Carbonic oxide is inflammable: it is inlamed by a lighted taper, though the flame of a taper imnersed in it is extinguished; the product of its combustion is arbonic acid. A mixture of carbonic oxide and oxygen gases

may be made to explode by flame, by a red-hot solid body, or by the electric spark. Carbonic oxide is irrespirable; when inspired, it acts on the system as a poison. Mr. Witter states that, on making three or four hearty inspirations of this gas, after having exhausted the lungs of common air as much as possible, the effect was an inconceivably sudden deprivation of sense and volition; he fell motionless on the floor.

185. Besides the compounds above described, carbon and oxygen form another compound, called *oxalic acid*, which will be noticed under the department of *Organic Chemistry*.

RECAPITULATION.

164. In what forms does Carbon occur in Nature?—166. How may the composition of the *diamond* be proved?—168. How is Charcoal procured from *Wood?* What are the properties of Wood Charcoal?—169. What is *Animal Charcoal?* For what purposes is it used?—174. In what forms does *Carbonic acid* occur in nature?—175. How may Carbonic Acid be procured?—176. What property is acquired by liquids, when charged with Carbonic Acid?—177. What are the properties of Carbonic Acid, with reference to *combustion?*—178. What, with reference to *respiration?*—179. How is its presence *tested?*—180. By what means may it be *liquefied?*—and *solidified?*—181. Explain the principle of *Woolfe's Apparatus.*—182. Explain *Nooth's Apparatus.*—183. What is *Carbonic Oxide?*—184. What are its properties?

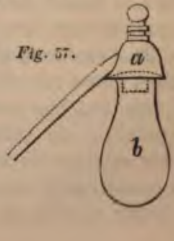
CHAPTER IX.

OF SULPHUR.

186. *General Remarks.*—Sulphur is one of the few substances which exist naturally in an elementary state. It occurs in great quantities in the mineral kingdom: it is exhaled from volcanoes in a pure state, or in combination with hydrogen, in which state it forms a very deleterious gaseous compound, called *sulphureted hydrogen;* it condenses in issures in the neighbourhood of volcanoes, and is there ound in a massive state, constituting *sulphur veins*, from which the principal part of the sulphur of commerce is btained. Sulphur is found in great abundance in combiation with several metals, as iron, lead, copper, silver, ntimony, and zinc; and it may be procured in large quanities, by exposing the iron ore, called *iron pyrites*, to a red eat in close vessels. Sulphur is also found, in a greater or ess proportion, in most animal, and in many vegetable, roducts; a small quantity is always found associated with lbumen, in the liquid state in the egg, in the solid state in he hair.

187. *Preparation of Sulphur.*—In order to obtain sulphur n a pure state, it must be *sublimed* (p. 127) in a vessel called an *alembic*. This apparatus consists of a body *b*, to which is fitted a head *a* of a conical shape, having ts base depressed lower than the neck of the body, so that the vapours which rise, and condense upon its sides, run down into the circular channel formed by its depressed part, and are thence conveyed by the nose or beak into a

Fig. 57.



receiver. The sulphur is put into the lower part *b*. The alembic is then placed in a vessel of sand, called a *sand-bath*, and this is heated by a furnace. By means of the sand-bath, the sulphur is fused more gradually and equably, than by placing it directly over a fire. When sufficiently heated, the sulphur rises in the form of a thick, white vapour, and condenses on the sides of the head in the form of a fine yellow crystalline powder, commonly called *flowers of sulphur;* from the minuteness of its particles it is sometimes called *flour* of sulphur. On washing this substance several times with water, pure sulphur is obtained.

188. *Properties of Sulphur.* — Sulphur, in its simple state, is a solid body, of a yellow colour, without taste or smell, but emitting a peculiar odour when rubbed. It is remarkably brittle: a roll of it, held in the hand, frequently breaks with a crackling sound. It is a non-conductor of electricity, and is excited negatively by friction. It fuses at 226°, and between this temperature and 280° it forms a clear liquid of an amber colour. When melted and thrown into cylindrical moulds, it forms the *roll sulphur* of commerce. At near 320° it begins to thicken, and acquires a reddish tint; and, between 428° and 482°, it becomes so thick that the containing vessel may be inverted without the sulphur running out. From 482° to its boiling point, it again becomes liquid, though not to the same extent as at 248°. When heated to 428°, and poured into cold water, it acquires the consistency of softened sealing-wax, and is used for taking impressions from seals. Sulphur is exceedingly volatile; it begins to evaporate before it is completely fused. At about 600°, it volatilizes rapidly, and its vapour condenses in close vessels in the form of the crystalline *flowers of sulphur*, above described.

189. Sulphur which has been fused has a tendency to *crystallize*, on cooling: the centre of a common roll of sulphur exhibits the crystalline arrangement. In order to procure sulphur in this state, some of it is melted in a stoneware *crucible* (see fig. 58), and allowed to cool till it begins to so-

lidify; the crust which forms over it is then broken, and the liquid portion poured out; on breaking the solid mass which remains, when quite cold, it is found to be lined with fine crystals. Sulphur is *dimorphous* (p. 133): in passing from a state of *fusion* to a high temperature, its form is a secondary modification of an oblique prism with a rhomboidal base; but, after being *dissolved* in sulphuret of carbon at a lower temperature, it is deposited in the form of an elongated octohedron with a rhomboidal base; the latter is the form of crystal found in native sulphur and in the flowers of sulphur.

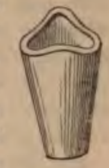


Fig. 58.

190. Sulphur is *inflammable*. When heated in the open air to 300°, it is inflamed, and burns with a pale-blue light. In oxygen gas, its combustion is much more vivid, and its flame is of a much lighter colour. Even at 190° it burns, but its combustion is so feeble that the quantity existing in gunpowder may be all consumed without explosion; this may be effected by spreading out the gunpowder on a hot tile. In these cases, the sulphur combines with oxygen, and emits copious fumes, consisting of sulphurous acid. Owing to its power of exhausting the oxygen of a confined portion of air by its combustion, and to the negative influence which sulphurous acid exerts upon the combustion of other bodies, sulphur is sometimes employed to extinguish combustion, as when a handful of lump sulphur is dropped into a burning chimney for the purpose of extinguishing the combustion.

191. *Sulphurous Acid.*—When sulphur is burned in common air or in oxygen gas, the combustion is attended by the formation of fumes, which consist of *sulphurous acid.* This compound consists of 1 equiv. of sulphur, and 2 of oxygen. For the purposes of experiment, pure sulphurous acid may be procured by heating three parts of oil of vitriol and two parts of mercury in a glass retort, and collecting the gas over mercury, as water would absorb it. The object, in this mode of preparation, is to deprive the oil of vitriol of

one equivalent of its oxygen; the metal employed for purpose decomposes a portion of the oil of vitriol, comb with part of its oxygen, and separates sulphurous while the oxidated metal unites, at the moment of its mation, with a portion of undecomposed oil of vitriol. W sulphur is burned in oxygen, this gas undergoes no ch of bulk; hence, sulphurous acid always contains its volume of oxygen.

[illegible] *Properties of Sulphurous Acid.*—Pure sulphu acid, at the common temperature and pressure, is a tra [illegible] gas, and is distinguished from all ot gaseous bodies by its pungent suffocating odour. It is [illegible] and extinguishes the flame of all burn substances which are immersed in it. It is fatal to animal [illegible] undiluted state; and, even when dilu [illegible] produces cough and uneasiness in [illegible] has remarkable bleaching pro [illegible] and then bleaches it; it [illegible] vegetable and animal subs [illegible]

osphoric aci[illegible]
of lime [illegible]
is evapora[illegible]
foun[illegible]
heate[illegible]
[illegible]

from the *fixed alkalies*, potash and soda, which are *left* [illegible] the ashes of inland and marine plants, respectively. Water absorbs several hundred times its bulk of this gas: a piece of ice, introduced into a jar of ammonia, is instantly liquefied, and the gas disappears in a few seconds. The concentrated solution of ammonia, formed by transmitting the gas into distilled water so long as it continues to be absorbed, is well known as the pungent liquid called *spirit of hartshorn*, being generally prepared from the horns of animals, and other animal matters; it is also called *liquor*, or *aqua ammoniæ*: and incorrectly, *liquid ammonia*. Under a pressure equal to 6·5 atmospheres (p. 168, note), and at the temperature of 50°, ammonia is condensed into a transparent colourless *liquid*: on removing the pressure, it again expands and assumes the gaseous state. Ammonia, in a pure state, is irrespirable. It extinguishes the flame of burning bodies, and is itself inflammable in a very low degree. The presence of free ammonia may always be *detected* by its pungent odour, by its transient action on yellow turmeric paper, by the dense white fumes which it forms when a glass rod, moistened with hydrochloric acid, is brought near it, and by its forming a deep blue solution with salts of copper.

II. HYDROGEN AND CARBON.

222. *Light Carbureted Hydrogen.* — This gas, frequently termed *heavy inflammable air*, *marsh-gas*, and *fire-damp*, may be readily procured by stirring the mud at the bottom of stagnant pools, and collecting the gas, as it escapes upwards, in an inverted glass vessel. In this state it contains 5 per cent. of carbonic acid gas, which may be removed by means of lime-water; and nearly the same proportion of nitrogen. Light carbureted hydrogen often accumulates in coal-mines, where, through defective ventilation, it gradually mingles with atmospheric air, and forms a mixture which explodes by the contact of flame. Light carbureted hydrogen consists of 1 vol. of *carbon vapour* (p. 224, note), and 2 vols. of hydrogen; but its combining

[illegible]

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224. *The principle upon which wire-gauze pr* *communication of flame*, may be readily explained is gaseous matter heated so intensely as to become ous; and Davy found that this degree of heat, is than that of solid bodies heated to whiteness. Now metals are rapid conductors of heat; when the flame fore, comes in contact with the wire gauze, its temp is so reduced by the conducting power of the metal, although the gas passes freely through the interstic is still very hot, it is not sufficiently so to become lum That wire-gauze does completely intercept the a burning body, may be proved by the following experiments. 1. If a piece of thick iron or brass wire be bent into a little ring, as represented in the figure, and this ring be gradually lowered over the flame of a candle until it surrounds the wick, the flame will be extinguished, owing to the w ducting away the heat with such rapidity, that the matter is cooled below the temperature necessary 2. If a piece of wire-gauze be placed over the lamp, as in the subjoined figure A, the hand may

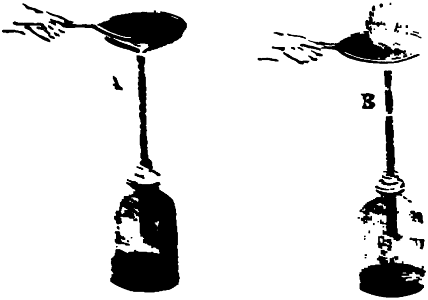

Fig. 4.

above the gauze as near to the flame as possib injury; but on removing the gauze, the heat endured by the hand in this position for a mom a bottle be filled with an inflammable gas and pipe be fitted to its neck, the gas may be inflamed as it escapes. If a piece of wire-gauze be held over the flame, as at A, the flame will be flattened, but will not pass through the gauze. If, on the other hand, the gas be inflamed *above the gauze*, as at B, it will burn freely, but the flame will not be communicated through the gauze to the contents of the pipe. 4. The same principle has already been illustrated in the apparatus of the *oxy-hydrogen blowpipe* (p. 152). 5. It is also found that the flame of coal-gas is incapable of passing through a sheet of wire-gauze, containing not fewer than 400 holes in the square inch.

225. *Coal and Oil Gases.*—These gases are procured from coal and oil, by heating them to redness in an iron retort. The *illuminating power* of a gas is in proportion to the quantity of carbon it contains. Thus, the flame of pure *hydrogen* affords a very feeble light; when combined with one proportion of carbon, in the form of *light carbureted hydrogen*, its light is greatly increased; and, when combined with another proportion of carbon, in the form of *olefiant gas*, it affords a brilliant and intensely luminous flame. It is also found that, the greater the density of the gas, the richer it is in carbon, and the more brilliant, consequently, will be its flame. The comparative illuminating powers of gases may, therefore, be estimated, by determining the relative quantities of the denser carburets of hydrogen which enter into their composition. *Coal-gas* contains less of the heavy carburets of hydrogen than *oil-gas*, and has, therefore, feebler illuminating powers. *Oil* consists principally of carbon and hydrogen, and therefore yields a gaseous product of comparative purity. *Coal*, on the other hand, contains a large quantity of oxygen and nitrogen, and hence, besides the heavy carburets of hydrogen, numerous compounds are formed, which are not only useless, but positively prejudicial to illumination.

226. *Structure of Flame.*—It has been already observed that *flame* is gaseous matter heated so intensely as to become luminous. Hence, the more completely the gaseous matter is consumed, the more intense and perfect will be its light. This will be *readily* understood from considering the *struc-*

ture of flame. The flame of a spirit lamp, of a candle, or of a gas jet, consists of three parts, or cones, as represented in the adjoining figure. 1. The innermost part, *a*, is a hollow cone, and consists of the combustible material in a state of vapour. 2. The intermediate part, *b*, is the luminous portion of the flame. The combustion of the materials is, however, not complete in this part, the supply of air being insufficient for that purpose; it is the hydrogen principally which burns, the carbon being separated in solid particles, which are heated white hot from the combustion of the gas, and give the luminousness to the flame; hence, Davy described luminous flame as always containing *solid matter heated to whiteness.* This part of the flame, possessing an excess of combustible matter at a high temperature, is a powerful agent in removing oxygen from metallic oxides, and reducing them to their metallic state. Hence this portion is called the *deoxidizing flame.* 3. In the external cone, *c*, the deposited carbon meets with oxygen from the surrounding atmosphere, and is entirely consumed. The greatest heat of the flame is found within this cone, near the point of *b*. The outermost part of the flame, being mixed abundantly with the oxygen of the air at a high temperature, is the proper part for kindling a combustible, and is called the *oxidizing flame.* Its properties are the reverse of those of the intermediate cone. According to the above account, *a* represents a cone of vaporized combustible; *b*, the sphere of partial combustion; and *c*, the sphere of complete combustion.—*Graham's Chemistry*, p. 424.

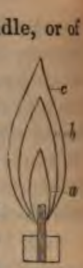

Fig. 65.

227. *Argand Burner.*—In the *Argand burner*, which is a lamp with a circular wick, and named from its inventor, complete combustion is promoted, by allowing the air to enter freely *within*, as well as on the outside of the inflammable matter. A result of the circumstances which determine the quantity of light from different flames, is, that the larger the flame till it begins to be smoky, the greater

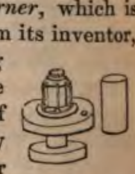

Fig. 66.

measure and equivalent are unknown. It is a tasteless, and nearly scentless gas; it is irrespirable, and it extinguishes the flame of all burning bodies; it is highly inflammable, and burns with a strong yellow flame. It has no effect upon litmus or turmeric paper.

223. *Safety Lamp.*—The accidents, formerly so frequent and so fatal in coal mines, arising from explosions of light carbureted hydrogen, led to the invention of the *Safety Lamp.* Davy found that the inflammable gas would not explode, if mixed with less than 6, or with more than 14 times its volume of atmospheric air; that neither red-hot iron nor red-hot charcoal was capable of exploding it; that the explosive mixture could not be fired in tubes of 1-7th of an inch in diameter; and that metallic tubes prevented explosion better than tubes of glass. Upon these principles he constructed the *Safety Lamp,* a figure of which is represented in the margin. A piece of fine *wire-gauze* may be regarded as an assemblage of short narrow tubes, which are impermeable to flame; consequently, a lighted lamp, completely surrounded by a cage of *wire-gauze,* may be introduced into the explosive atmosphere, without fear of kindling it. Further than this, the safety lamp indicates to the miner the precise moment of danger. When carried into an atmosphere of light carbureted hydrogen, the flame of the lamp begins to enlarge; and the mixture, if highly explosive, takes fire as soon as it has passed through the wire-gauze, and burns on its inner surface, while the flame of the lamp itself is extinguished. This is the signal for the miner to withdraw; for, although the flame should not be able to communicate with the explosive atmosphere surrounding the *outside* of the lamp, so long as the texture of the gauze remains entire, yet the heat evolved during the combustion *within* is so great, that, in a few minutes, the wire would undergo oxidation and fall to pieces.

Fig. 62.

able odour, resembling that of putrefying eggs, which, i fact, owe their odour to the emission of this gas. It con of 2 vols. of hydrogen, and 1-3rd vol. of sulphur vapour, whi are condensed, by combination, into 2 vols. of the compo gas. Under a pressure of 17 atmospheres at 50°, sulp retted hydrogen is condensed into a limpid colourless *liqu* which resumes the gaseous form on removal of the pres This gas is very injurious to animal life: birds perish an atmosphere containing 1-1500th, a dog in air contain 1-800th, and a horse in air containing 1-250th, of its volu of this gas. Sulphureted hydrogen extinguishes flame, b is itself highly combustible, burning with a pale-blue flame; its combustion is attended by the formation of water a sulphurous acid, and the deposition of sulphur. *Sulphure* *mineral waters* contain this gas, but its proportion is rarely more than 1½ per cent. of their volume.

230. *Test for Metals.*—Sulphureted hydrogen is a very valuable *test for metals*. The method employed for thi purpose is very simple, and is illustrated in the adjoining figure. The materials for forming the gas may be introduced into a flask, furnished with a bent tube; the metal to be tested is dissolved by means of nitric acid, and the solution placed in a glass. The tube is dipped into the glass, and the gas passes into the solution. If the metal be lead, the solution becomes *black;* if arsenic, *yellow;* if antimony, *red;* if zinc, *white*. Sulphureted hydrogen blackens solutions of many metals besides lead; but these may be distinguished from each other by various tests. Sulphureted hydrogen is a re-agent of frequent application, and is of considerable importance. A solution of sulphureted hydrogen in water may be often advantageously used for testing metals, instead of the gas itself.

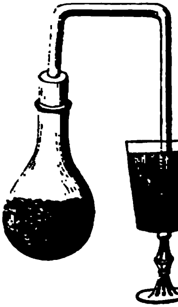

Fig. 67.

[illegible]

F THE METALLIC ELEMENTS

CHAPTER XV

RAL CONSIDERATIONS OF METALS

l Remarks.—There are forty-two *Elementary*
s. Of these, seven only were known to the
gold, silver, iron, copper, mercury, lead, and
the others are of recent discovery. The
tributed in vast quantities throughout the
sent a variety of forms, according to the
which they are found associated, as oxygen,
ur, and several acids. Metals seldom occur
y state, but are separated from their ores
cult and complicated processes. When they
re state, they are termed *native*; when they
with other bodies, they are said to be *mine-*
combination of a metal with a mineralizing
lled an *ore*. Ores are found in large fissures
d *veins*; and often in beds of earth. Com
e metals with each other are called *alloys*
the characteristic physical properties of the
hen mercury is one of the constituents, the
led an *amalgam*. All the metals are conduc-
d of electricity; they are all positive electrics
us, opaque, and refuse to transmit light
general good reflectors of light. Metals
non-metallic bodies, combine with oxygen
and *oxides*; the latter are the more frequent
m of Arrangement of the Metals has been
p. 5—7.

escapes in the form of dense white fum be introduced into a jar of this gas, it i tied, and the whole of the gas disapp On opening a long and wide jar of this absorption of the gas is so instantaneous, in the jar with the same violence as if w The *hydrochloric acid of commerce* is formed by transmitting the gas into wate of it is absorbed. A mixture of two me and one of nitric acid constitutes *aqua* known for its property of dissolving gold

VII. NITROGEN AND CARBO

238. *Cyanogen Gas.*—The name of th from κυανος, blue, and γεννάω, I generate, fr ing an essential ingredient in *Prussian* carburet of nitrogen. It is prepared by h of mercury, a compound of mercury and a glass retort; the cyanide is resolved into and cyanogen gas, which must be collec Cyanogen gas is colourless, and has a str very peculiar odour. This gas consists of vapour,* and 2 vols. of nitrogen, which a combination into 2 vols. of the compound pressure of 3·6 atmospheres, and at 45°, it i a limpid *liquid*, which resumes the gaseous ing the pressure. Cyanogen gas burns w purple flame in air or oxygen. Cyanogen f compound with hydrogen, called *hyd* belongs to the department of organic

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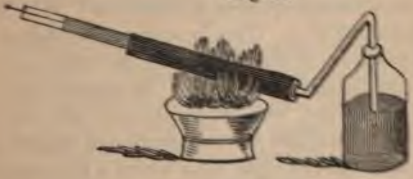
* Vapour is a hypothetical substance, for ed in the insulated form of vapour. W al works, it denotes the *condition of* c

VII. CARBON AND SULPHUR.

234. *Bisulphuret of Carbon.*—Sulphur and carbon may be made to combine by transmitting the vapour of sulphur over fragments of charcoal, by the following process. Small pieces of charcoal are placed in an earthen tube of about an inch and a half in diameter. To one end of this earthen tube is adapted a glass tube filled with small pieces of sulphur, which may be pushed forward by means of a wire passing air-tight through a cork. To the other end of the earthen tube is fixed a bent tube of glass, which terminates below the surface of some water contained in a bottle. The earthen tube is then inclined across the flame of a chafing dish, until it becomes red-hot, when the sulphur must be pushed forward and brought in contact with the ignited charcoal. Bubbles of gas immediately escape under the water in the bottle, and a vapour appears, which will condense under the water into a *liquid*. This is *bisulphuret of carbon*, mixed with water, which may be separated from it by distillation in a retort containing a little chloride of calcium, a substance which absorbs water very rapidly. Bisulphuret of carbon is very inflammable, and kindles in the open air at a temperature scarcely above that at which mercury boils. With oxygen gas, it forms an explosive mixture. It is exceedingly volatile, and may hence be em-

Fig. 69.



PROPERTIES OF METALS.

236. The further general consideration of the Metals, m
be arranged under the following heads:—

- I. General Properties of Metals.
    - 1. *Hardness and Elasticity.*
    - 2. *Density.*
    - 3. *Crystalline Texture.*
    - 4. *Malleability.*
    - 5. *Ductility.*
    - 6. *Tenacity.*
    - 7. *Fusibility.*
    - 8. *Volatility.*
- II. Oxidation of Metals.
    - 1. *Calcination.*
    - 2. *Deflagration.*
- III. Reduction of Metals.
    - 1. *By Heat alone.*
    - 2. *By Heat and Combustible Matter.*
    - 3. *By the Galvanic Battery.*
    - 4. *By Deoxidizing Agents.*

I. GENERAL PROPERTIES OF METALS.

237. *Hardness and Elasticity.*—Metals are generally
hard substances: their relative hardness to each other
however, not been determined. Among the hardest
placed iron, zinc, copper, manganese, nickel, titanium
palladium; gold, silver, and platinum, are of a
quality: lead is still softer than these; and potassium
sodium are so soft as to yield to pressure of the f
The property of *elasticity* is connected with that of
ness, the hardest metals being also the most elastic.
sonorous quality of metals is allied to their hardnes
elasticity (see p. 111); in these respects, iron and c
are conspicuous.

238. *Density.*—The most *dense* substances in natu

found among the metals. Gold, for instance, is upwards of 19 times, and platinum nearly 21 times, heavier than an equal bulk of water. But density is not an essential character of metals: potassium and sodium are so light as to float upon the surface of water. Some metals become denser on being hammered, their particles being brought together permanently by the operation.

239. *Crystalline Texture.*—Many of the metals are capable of assuming crystalline forms, which are, generally, those of the *cube* and the *octohedron.* The facility of procuring metallic crystals is proportionate to the lowness of the temperature at which a metal fuses: bismuth conducts heat less perfectly than other metals, and therefore yields crystals most readily. The mode of procuring metallic crystals is the same as that described at p. 190 for procuring crystals of sulphur. The texture of iron is *fibrous;* that of zinc, bismuth, and antimony, *lamellated*, or in minute plates.

240. *Malleability.*—Many of the metals are capable of being extended into thin plates or leaves under the hammer, and are termed *malleable* metals. This property depends upon a high degree of *tenacity* connected with a certain degree of *softness.* Gold is the most malleable of the metals: a grain of gold may be extended so as to cover 50 square inches of surface, and to have a thickness not exceeding 1-282,020th of an inch; it may thus present two millions of visible points. Zinc is malleable in the highest degree between 300° and 400°; and iron at a temperature exceeding that of a red heat. Some metals are either very slightly malleable, or, like antimony, arsenic, and bismuth, actually brittle. Metals which have become brittle, either in consequence of fusion, or of long-continued hammering, are again rendered malleable by *annealing*—the process of heating a metallic body, and allowing it to cool in a moderate temperature. A few of the malleable metals can be *welded*, or portions of them joined together by hammering. Iron and platinum may be welded together at a bright-red heat, and fragments of potassium may be made to adhere

to whom it was given as a medicine, sometimes occurs native, but is generally procured from its sulphuret. This ore, formerly called *stibium*, was long regarded as the metal itself, and was termed antimony, or *crude antimony*, while the pure metal was termed *regulus of antimony*.* On heating the sulphuret of antimony in a crucible with half its weight of iron filings, sulphuret of iron is formed, and metallic antimony is separated. Antimony is a white, brittle metal, of considerable lustre. At 797° it fuses, and, on cooling, acquires a highly lamellated texture, and sometimes yields crystals. It burns in air at a red heat, with the production of copious fumes, which condense on cool surfaces, frequently in the form of small shining needles of silvery whiteness, formerly called *argentine flowers of antimony*; they are the oxide of antimony.

302. *Glass, Liver, and Crocus of Antimony.*—These are *oxy-sulphurets* of antimony, and are used in pharmaceutical preparations. They are made by roasting the native sulphuret, so as to form sulphurous acid and oxide of antimony, and then vitrefying the oxide together with undecomposed ore, by means of heat. The product will, of course, differ according as more or less of the sulphuret escapes oxidation during the process.

303. *Kermes Mineral; Golden Sulphuret.*—When sulphuret of antimony is boiled in a solution of potassa or soda, a liquid is formed, from which, on cooling, an orange-red substance is deposited, called *kermes mineral*. On adding dilute sulphuric acid to the remaining liquid, a substance is precipitated, called *golden sulphuret*, which contains more sulphur than kermes mineral, and no potassa.

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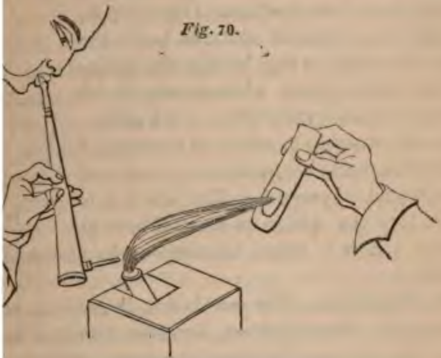
* The term *regulus* was originally applied by the alchemists to metallic matters when separated from other substances by fusion; it originated in their expectation of always finding gold, the *king* of metals, at the bottom of their crucibles, after fusion. The term was afterwards applied to the metal extracted from the ores of some of the metals, which formerly bore the name which is now given to those metals themselves; hence, regulus of antimony—of arsenic—of cobalt.

e *Blow-Pipe.*—The *fusibility* of metals is ascer-
eans of an instrument called a *blow-pipe.* Every
e most violent heat of a furnace may be produced
e of a candle or lamp, directed upon a small por-
etal by this means. This instrument consists of
ss tube of about one-eighth of an inch in diameter
, and tapering at the other end to a much smaller
to admit the escape of a very fine jet of air. For
urposes, the tube is enlarged gradually, as shown

Fig. 70.



igure above, to admit of the accumulation of a
antity of the breath. The substance to be sub-
the action of the blow-pipe, must be placed upon
f charcoal, or in a small spoon of platinum, gold,
. When a large flame is required, a lamp with a
k must be employed, and the air supplied by means
ws, in the manner adopted by workers in glass.
tense heat is required, the oxy-hydrogen blow-pipe
is used. The blow-pipe is chiefly employed to
whether a substance be fusible *per se;* whether it
e by heating it with a flux or re-agent; whether it
volatile matter by heat; whether a metallic oxide

by pressing them together by the hand at the ordinary temperature of the air.

241. *Ductility.*—Most of the malleable metals admit of being drawn out into wire, and are called *ductile* metals. The ductility of metals is, however, not always proportional to their malleability; iron, for instance, may be drawn into very fine wire, but it cannot be beaten into very thin leaves. Wollaston formed a gold wire so thin as to be only 1-5000th of an inch in diameter; 550 feet of it weighed only one grain; an ounce of it would extend fifty miles. He also obtained a wire of platinum of not more than 1-30,000th of an inch in diameter.

242. *Tenacity.*—The tenacity of different metals is determined by ascertaining the weight which a wire of a certain thickness can support without breaking. This property appears to be highest in iron, and lowest in lead. The tenacity of different metals is shown in the following table, in which the diameter of each wire is the 0·787th of a line:—

Iron wire supports a weight of .	549·25 lbs.
Copper . . .	302·278
Platinum . . .	274·32
Silver . . .	187·137
Gold . . .	150·753
Zinc . . .	109·54
Tin . . .	34·63
Lead . . .	27·621

It has been found that the tenacity of wires of iron, copper, and brass, is much impaired by *annealing* them.

243. *Fusibility.*—The metals, with the exception of mercury, are all solid at the temperature of the air; but they may all be liquefied by heat. The degree at which they *fuse*, or their *point of fusion*, is very different for different metals: some of them are fusible below a red heat, as tin, lead, zinc, &c.; most of them are infusible below a red heat; iron and manganese require for their fusion the highest heat of a smith's forge; and many, as platinum, are fusible only before the oxy-hydrogen blow-pipe.

and allows the metallic particles, as they are separated, to subside in it and accumulate together. A substance of this kind is termed a *flux*. A flux may act in different ways: it may merely melt, and allow the metallic particles to fall through it; or it may combine, as it melts, with ingredients mechanically mixed, in a minute state of division, with the ore, forming with them a very fusible compound, called a *slag*, through which the reduced metal may fall; or, it may affect chemically some of the ingredients combined with the metal in the ore, forming with them the fluid matter through which the metal is deposited. Alkaline fluxes are generally used; their effect is to render the earthy mixtures fusible by converting them into glass. *Crude flux* is a mixture of nitre and crystals of tartar. *White flux* is a pure carbonate of potassa. *Black flux* is carbonate of potassa mixed with carbon. A very fusible flux for experiments on the small scale is prepared by mixing 5 parts of carbonate of potassa with 4 parts of carbonate of soda.

253. *Reduction by the Galvanic Battery.*—This is a still more powerful agent than the preceding. Some oxides, which resist the united influence of heat and charcoal, may be reduced by the agency of Galvanism. When reduction is effected by this means, the metal always appears at the negative pole of the battery.

254. *Reduction by Deoxidizing Agents.*—Metals are reduced from solutions of their oxides by means of deoxidizing agents. If phosphorous acid be added to a liquid containing oxide of mercury, oxygen is taken from the oxide, phosphoric acid is formed, and metallic mercury subsides. Metals are occasionally employed for reducing other metals from their combinations, when dissolved in water; in such cases, the affinity of the former for oxygen must exceed that of the latter. Thus, iron precipitates copper from the sulphate in solution, and takes its place. Mercury, added to a solution of nitrate of the oxide of silver, precipitates metallic silver, and passes into the state of oxide of mercury, which is dissolved in the nitric acid. On introducing metallic copper

into this liquid, pure mercury is thrown down, and a nitrate of the oxide of copper formed; and this may be precipitated by means of iron. In cases in which the metallic compound to be reduced is insoluble in water, decomposition may often be effected by boiling the compound together with the decomposing metal, in water. Thus, zinc, boiled in water with the chloride of silver, combines with the chlorine, and is dissolved; the silver is separated from the insoluble chloride in a minute state of division.

RECAPITULATION.

235. In what state are the Metals generally found?—236. What are the general properties of Metals?—237. Enumerate some Metals with reference to their *hardness*—238. to their *density*—239. to their *crystalline texture*—240. to their *malleability*—241. to their *ductility*—242. to their *tenacity*—243. to their *fusibility*.—244. Explain the principle of the *Blow-pipe*. For what purposes is it employed?—245. Explain the principle of the *Alcohol Blow-pipe*.—247. What are the comparative affinities for oxygen of potassium, of iron, of copper, of mercury, of gold, &c.? 248. What is *Calcination*?—249. What is *Deflagration*?—250. What is meant by *Reduction* of Metals?—251. Explain the process of reduction by heat alone—252. by heat and combustible matter—253. by the Galvanic battery—254. by deoxidizing agents.

CHAPTER XVI.

OF THE METALS.

DIV. I. METALLIC BASES OF THE ALKALIES.

255. The alkalies, potassa, soda, and lithia, are oxides of peculiar metals, termed *potassium*, *sodium*, and *lithium*. These are called *kaligenous metals*, from the word *kali*, an old name of potassa, used in a general sense to denote an alkali. They were first procured by Davy, by decomposing their oxides by means of Galvanism; oxygen appeared at the positive, and the metals at the negative, pole of the battery.

256. POTASSIUM.—*Potassium*, or *kalium*, is solid at common temperatures, but it is so soft that it yields to the pressure of the fingers; at 32°, it is brittle; at 150°, it melts; at a temperature below that of redness, it passes into vapour. It is considerably lighter than water, and floats upon this liquid. It has a powerful affinity for oxygen, and oxidizes rapidly by contact with liquids which contain this gas; a fresh surface, exposed to the air, is almost instantly covered by a dull film of oxide. Potassium decomposes water at the instant of touching it, with the evolution of so much heat, that the metal takes fire, and burns vividly as it moves over the surface of the water; the brilliancy of the flame is increased by the combustion of the hydrogen, which takes fire during its separation; a globule of fused *potassa* remains floating on the water, but in a few seconds, as its temperature falls, it produces an explosion of steam—a phenomenon similar to that produced by a drop of water thrown upon a hot metallic

c up (p. 54). If potassium be plunged under water, a violent reaction takes place, potassa alone is formed, and hydrogen gas escapes. Owing to its affinity for oxygen, potassium should be preserved under the surface of a liquid, which contains no oxygen, as naphtha.

257. *Potassa.*—Potassa is the oxide of potassium. It is prepared in the *anhydrous* state, in the form of a white powder, by exposing thin slices of potassium to dry air. When potassium is put into water, a *hydrate* is formed, commonly called, from its energetic action upon the animal textures, *caustic potash*. This substance may be prepared by evaporating a solution of bicarbonate of potassa, and boiling the crystals, thus obtained, with their own weight of hydrate of lime and water; the resulting liquor is a solution of caustic potash; if it be required in the solid state, the liquor must be boiled down in a silver or bright iron vessel, and out of contact with the air. Caustic potash has a strong affinity for oxygen, and is employed for depriving gases of hygrometric moisture, and for forming freezing mixtures.

258. *Nitre.*—Nitre, or *salt-petre*, is the nitrate of potassa. It is generated spontaneously in the soil, and crystallizes on the surface, in several parts of the world. It is prepared, in some parts of the continent, in artificial nitre-beds, in which nitrate of lime is first formed, and then converted into nitrate of potassa by adding wood-ashes to the ley. Nitre crystallizes readily in long six-sided prisms; it fuses by a heat under redness, and is then poured into moulds, forming *sal-prunelle*. Nitre is chiefly used in chemistry as an oxidizing agent, and in the formation of nitric acid. In the arts, it is much used for making deflagrating mixtures: *gunpowder*, for instance, is a mixture of about one equivalent of nitre, one of sulphur, and three of carbon. In this and all other deflagrating mixtures containing this salt, the oxygen of the nitre is the active ingredient in promoting the rapid combustion of the inflammable matter.

259. *Potashes; Pearl-ash; Salt of Tartar, &c.*—These are carbonates of potassa. 1. *Potassa* exists in combination

with clay and other minerals, which form the earthy part of soil; it appears to be essential to vegetation, being found in the sap of plants, in combination with vegetable acids. Hence, when land plants are dried and burned, their ashes lixiviated, and the solution evaporated to dryness, the salts of the vegetable acids are found to have been destroyed, and carbonate of potassa remains. 2. The potashes of commerce, when partially purified by solution, evaporation, and heating in a furnace, constitute the *Pearl-ash* of commerce. 3. A very pure carbonate is formed by burning together two parts of *cream of tartar* (bitartrate of potassa), and one of nitre. In this process the tartaric acid of the cream of tartar is completely decomposed, and carbonate of potassa remains mixed with charcoal, from which it may be separated by solution and filtration. The pure carbonate is called *Salt of Tartar*. 4. *White* and *Black Flux* are carbonates of potassa, and are employed in the reduction of metals (p. 235).

260. *Tartar; Cream of Tartar.*—These are bitartrates of potassa. They are found encrusted on the sides and bottoms of wine casks, where, owing to their insolubility in alcohol, they have been deposited from the juice of the grape.

261. SODIUM.—Potassium is the alkaline metal of the vegetable kingdom; *sodium*, or *natrium*, is its analogue in the animal kingdom, its salts being found in all animal fluids. Sodium is very lustrous, and has the aspect of silver. At common temperatures it is so soft that it may be cut with a knife, and yields to pressure of the fingers. At 194° it is perfectly liquid. It tarnishes on exposure to the air, though its oxidation is less rapid than that of potassium; when heated nearly to redness, it takes fire and burns with a yellow flame. Thrown on cold water, it swims on the surface, and undergoes rapid oxidation, but without taking fire, like potassium. If a few drops only of water are applied to sodium, it readily becomes hot enough to take fire. In each case, *soda* is formed, and the water acquires alkaline properties.

262. *Soda.*—Soda, or *natron*, is the oxide of sodium, and is formed when this metal is exposed to the air or to water. When combined with water as a hydrate, it is the *caustic soda* of chemists. This substance may be prepared from the bicarbonate of soda, by a process similar to that for preparing caustic potash, and may be solidified in the same way. Soda is readily distinguished from potassa and other alkaline bases by the following characters:—1. It forms with sulphuric acid a salt well known as *Glauber's salt*. 2. All its salts are soluble in water, and cannot be precipitated by a re-agent. 3. Its salts impart a rich yellow colour to flame.

263. *Sea salt; common salt.*—Sodium burns in chlorine, and forms chloride of sodium, or common culinary salt. The different kinds of common salt are procured from the mineral *rock-salt*, or by evaporating sea-water. Sea-water contains 2·7 per cent. of chloride of sodium, which is the most considerable of its saline ingredients. In places on the coast where spontaneous evaporation proceeds rapidly, sea-water is retained in shallow basons or canals, on the surface of which a saline incrustation forms with the progress of evaporation, and is afterwards broken and raked out. On evaporating a solution of salt in water rapidly, it crystallizes in hollow, four-sided pyramids; but it occurs in regular cubic crystals, when the solution is allowed to evaporate spontaneously. The glazing of pottery is effected by decomposition of chloride of sodium: a quantity of this substance is thrown into the kiln, where it is converted into vapour by the heat, and, condensing upon the surface of the pottery, causes its vitrification.

264. LITHIUM.—*Lithium* is a white metal, resembling sodium, and of highly oxidable quality. *Lithia* is the protoxide of lithium, and it occurs in small quantities in certain minerals; it possesses all the properties of an alkali, and differs from potassa and soda in the very sparing solubility of some of its salts. Lithia has been hitherto obtained only in small quantity.

perature; it is infusible in the most powerful furnaces, but melts in the flame of the oxy-hydrogen blowpipe, or by means of Galvanism. Platinum is used in the construction of crucibles, in cases in which acids are employed which would act upon other metals, or upon glass; it is also used in the form of a conducting wire in electric and galvanic batteries. The remarkable property of spongy platinum in causing the union of oxygen and hydrogen gases, has been already noticed (p. 151).

328. *Aphlogistic Lamp.*—The principle of the Aphlogistic, or *flameless*, lamp depends upon the slow combustion of inflammable or explosive substances at a lower temperature than is necessary for inflammation. In the annexed figure, A represents a vessel, which is supplied with alcohol by an aperture at C. A glass tube, B, of several inches in length, is fitted to the vessel by means of a wooden cork. Within the glass tube is a coil of platinum wire, wound round a piece of wood, which tapers upward in a conical form; a communication between the wire and the alcohol is effected by means of a piece of wick. When the lamp is to be used, the platinum may be ignited by the flame of a candle; the wire will remain red hot, and emit a feeble light, so long as there is any alcohol in the vessel. A cylinder of camphor may be substituted for both the wick and the alcohol.

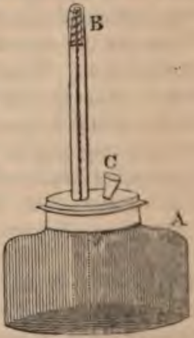


Fig. 74.

329. Palladium, Rhodium, Osmium, Iridium.—These four metals are found in the ore of platinum. When the ore is digested in hydrochloric acid, the platinum, together with palladium, rhodium, and other metals, is dissolved; while a black powder remains, which consists of osmium and iridium. These metals are procured in very small quantities, and their properties are very imperfectly known; they

coal, and lime, in a *blast furnace*. This form of furn
appears to combine the following advantages:—1. A g
surface is exposed to the air,
which, having an easy entrance,
rushes through the fuel with
great rapidity; 2, the inclined
sides act in some measure as
reverberating surfaces; and, 3,
the fuel falls of itself. The air
is thrown in at two or more
openings near the bottom, from
a blowing apparatus, so as to
maintain the whole contents of
the furnace in a state of intense
ignition. In the process, as thus
conducted, the carbon removes
the oxygen from the iron, form-
ing carbonic oxide or carbonic acid, which escapes.
lime acts the part of a *flux*, by combining with the e
matter of the ore, and forming a fusible compound, cal
slag, through which the melted iron falls, and collects
bottom of the furnace. The slag is let off from time to
at an aperture in the side of the furnace, and the fused
is carried off by a hole in the bottom of the furnace, rec
into channels formed in sand, and thus *cast* into ing
pigs, commonly called *pig-iron*.

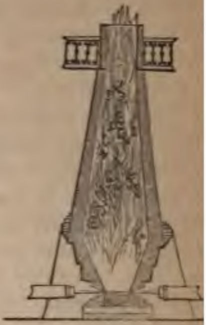


Fig. 72

283. *Steel.*—Steel is a carburet of iron. The ge
method of forming steel is by the process of *cement*
This consists in placing alternate layers of bars of mal
iron, and of powdered charcoal, in a large furnace,
which the atmospheric air is entirely excluded, and ke
the whole for several days at a red heat. By this mea
iron gradually combines with from 1-3^{d} to 1·75th per ce
carbon; and the different degrees of temperature to wh
is subjected, occasion the varieties in its state of coh
or *temper*, which are adapted for making different in
ments.

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tained. Its va

tarnishes on exposure to the air, forming a grey oxide, called *fly-powder.*

297. *Fuming Liquor of Arsenic.*—When powdered arsenic is thrown into a vessel filled with dry chlorine gas, it takes fire, and *sesquichloride* of arsenic is formed. This is a colourless volatile liquid, which *fumes* strongly on exposure to the air, and is resolved by water into the hydrochloric and arsenious acids.

298. *Realgar and Orpiment.*—These compounds are *sulphurets* of arsenic, occurring in the mineral kingdom. 1. *Realgar* is a crystalline, transparent, ruby-red substance, formed artificially by heating arsenious acid with about half its weight of sulphur, to the state of fusion. 2. *Orpiment* is a yellow crystalline substance, of a brilliant, but not very durable colour, and may be prepared by fusing together equal parts of arsenious acid and sulphur. It is the colouring principle of the paint called *King's yellow.*

299. CHROMIUM.—*Chromium* is prepared, by a difficult process, from the mineral called *chrome iron.* It is a greyish-white metal, brittle, and very infusible. The *oxide of chromium* is of a *green* colour, and, when fused with borax or other vitreous substances, it communicates to them a beautiful green colour, a property which affords an excellent test of its presence, and renders it exceedingly useful in enamelling, and in glass and porcelain painting. The emerald owes its colour to the presence of this oxide. Oxide of chromium is also the colouring matter of *pink,* applied to stoneware. *Chrome yellow* is the chromate of lead; it furnishes to the painter his best and most lively yellow. *Chrome red* is the bichromate of potassa.

300. VANADIUM, MOLYBDENUM, TUNGSTEN, COLUMBIUM.—These metals are of very rare occurrence, and are with great difficulty reduced to the metallic state from their ores. They are but imperfectly known, and have not been applied to any useful purpose.

301. ANTIMONY.—Antimony, said to have derived its name, *anti-moine,* from its fatal effects upon some monks

332. *Vegetable Chemistry.*—All the compounds of the Vegetable, as well as those of the Animal Kingdom, are termed *proximate principles*, as being the more immediate objects of sense; the elements of which they consist are called the *ultimate principles*. The *Proximate Principles of Vegetables* have been arranged by Turner under the following divisions:—

1. *Vegetable Acids.*
2. *Vegetable Alkalies.*
3. *Neutral Substances.*
4. *Oleaginous, resinous, and bituminous Substances.*
5. *Spirituous and ethereal Substances.*
6. *Colouring Matters.*
7. *Substances not referable to the preceding divisions.*

I. VEGETABLE ACIDS.

333. *General Remarks.*—Vegetable acids are compounds which are peculiarly the product of vegetation, and which possess the properties of an *acid*. They do not present a constant analogy in their composition; it seems, however, to be true that all vegetable substances are acid, which contain more oxygen than is required to form water with their hydrogen. Vegetable acids are decomposed by a red heat; nearly all of them are decomposed by concentrated hot nitric acid, by which they are converted into carbonic acid and water.

334. *Oxalic Acid.*—Oxalic Acid exists ready formed in several plants—associated with potassa in some species of sorrel, and with lime in several species of lichen. Oxalic acid may be prepared artificially by digesting sugar with about six times its weight of nitric acid, and expelling the excess of this acid by distillation; a syrupy fluid remains, which, on cooling, yields crystals of oxalic acid, which are purified by repeated solution in pure water, and re-crystallization. Oxalic acid consists merely of carbon and oxygen;

it contains no hydrogen; it appears, therefore, that the production of this acid depends upon the sugar being deprived of all its hydrogen, and of a portion of its carbon by oxygen derived from the nitric acid; hence, oxalic acid differs from carbonic acid only in the relative proportions of its ingredients; oxalic acid contains more oxygen than any other vegetable or animal substance. Oxalic acid is an active poison, and is liable to be mistaken for Epsom Salt. These substances may, however, be easily distinguished by the following circumstances:—1. Oxalic acid has an *acid taste;* Epsom salt has a bitter saline taste. 2. Thrown on red-hot cinders, oxalic acid is completely dissipated; in the case of Epsom salt, a white mass remains. 3. Oxalic acid is reddened by vegetable blues; Epsom salt is not affected by them. 4. With alkaline carbonates oxalic acid effervesces; Epsom salt gives with them a white precipitate. The *antidotes*, in case of poisoning with oxalic acid, are chalk and magnesia: oxalates are thereby formed, which are insoluble and inert.

335. *Acetic Acid.*—Acetic acid exists ready formed in the sap of many plants, either free or combined with lime or potassa; it is formed during the destructive distillation of vegetable matter, and is an abundant product of the acetous fermentation. 1. *Vinegar* is an impure acetic acid, prepared by fermentation from an infusion of malt, or from weak wine. Vinegar, although so different from sugar in its properties, is considered to be precisely analogous in its composition, both of them being binary compounds of water and carbon. There is this difference, however, between them: vinegar may be formed artificially, by fermentation, from sugar; but sugar cannot by any artificial process be formed from vinegar. 2. *Distilled Vinegar* is pure acetic acid diluted with water, and containing a small quantity of a peculiar oil formed during distillation, and, hence, termed *empyreumatic*. 3. For chemical purposes, acetic acid is prepared by the distillation of wood, and is hence termed *pyroligneous acid*. Pure acetic acid is exceedingly pungent, and blisters the skin, on contact;

it is very volatile; its vapour is inflammable, and burns with a white light.

336. *Tartaric Acid.*—Tartaric acid exists in the juice of several acidulous fruits, usually in combination with lime or potassa. It may be prepared by boiling a mixture of cream of tartar and chalk in water; an insoluble tartrate of lime subsides; on digesting this with sulphuric acid, tartaric acid is set free, and may be procured by evaporation in prismatic crystals. These crystals, when digested in nitric acid, are converted into oxalic acid.

337. *Hydrocyanic Acid.*—Hydrocyanic, or ***Prussic***, acid is contained in some plants; the distilled water from the leaves of the ***Prunus lauro-cerasus*** owes its poisonous properties to the presence of this acid. Hydrocyanic acid is prepared by various processes from the bicyanuret of mercury, or the cyanuret of potassium. The pure acid is a colourless liquid, of a strong odour, similar to that of peach blossoms. It is a powerful poison: a single drop introduced into the throat of a large dog, occasions death, after a few hurried inspirations. When a drop of it is placed on a piece of glass, it becomes solid, owing to the cold produced by the evaporation of one portion of it being so great as to freeze the remainder. Hydrocyanic acid is a compound of cyanogen (p. 224) and hydrogen.

338. *Other Vegetable Acids.*—1. *Citric Acid* is prepared by adding the juice of limes or lemons to chalk, and decomposing the citrate thus formed, according to the process adopted in preparing tartaric acid. 2. *Malic*, also called *Sorbic Acid*, is procured from the berries of the Sorbus aucuparia, or Service-tree; it is contained in most acidulous fruits, in which it is frequently associated with tartaric and citric acids. 3. *Gallic Acid* is obtained principally from gall-nuts, by exposing an infusion of them for some weeks to the air. It is particularly distinguished by the dark colour which it produces with peroxide of iron; the compound of these bodies forms the basis of *ink*. 4. *Benzoic Acid* exists in gum benzoin, in storax, in the balsams o

Peru and Tolu; and in the urine of herbivorous animals, being probably derived from the grasses on which they feed. The acid is commonly prepared by sublimation from gum benzoin. 5. *Lactic Acid* is found in the juice of the beet-root, in sour milk, and in most animal fluids. 6. *Succinic Acid* is prepared by distillation from amber. Numerous other acids have been described, but they are of comparatively little importance.

II. VEGETABLE ALKALIES.

339. *General Remarks.*—Vegetable alkalies, or *alkaloids,* are compounds which have *alkaline* properties. They present a remarkable analogy of composition: a single equivalent of each alkali contains exactly one equivalent of *nitrogen.* Their alkalinity has been attributed to the presence of ammonia, formed by the union of their nitrogen with a portion of hydrogen; this opinion is rendered more probable by their always evolving *ammonia* in the process of destructive distillation. The vegetable alkalies never exist in an insulated state, but always in combination with acids, with which they form salts, which are more or less soluble in water. The vegetable alkalies agree in several of their leading chemical properties, and they are all prepared by the same process with slight variation. The vegetable salt, containing the alkali, is first extracted by digestion, or maceration; the acid is then separated from it by some more powerful salifiable base, as potassa, ammonia, &c.; and the remaining alkali is purified by repeated solution and crystallization. Iodine combines with most of the vegetable alkalies in atomic proportions.

340. *Vegetable Alkalies.*—1. *Morphia* exists in opium in combination with meconic acid. It is one of the most important of the vegetable alkalies, and is the principle on which the narcotic properties of opium depend. Morphia is procured in the form of prismatic crystals. In its pure

state, it is almost inert; but, in solution, it is an energetic poison, alarming symptoms having been produced by so small a quantity as half a grain. The action of morphia with iodic acid is peculiar: the acid is decomposed, and iodine liberated, which may then be detected by *starch* (p. 208). A single grain of morphia in 7000 grains of water may be detected by this test. Besides morphia, opium contains other alkaline principles, as *narcotine*, *codeia*, *narceia*, *thebaia*, and *meconia*.—2. *Quina* and *Cinchonia* have been discovered in the different species of Cinchona bark, in combination with Kinic acid. These alkalies, though very analogous to each other, are distinctly different, standing in the same relation to each other as potassa and soda. Cinchonia readily crystallizes; quina does not crystallize; the alkaline properties of both are strongly marked.—3. *Strychnia* occurs in the *Strychnos nux vomica*, in combination with igasuric acid. It is procured in the form of minute prisms. It is an exceedingly virulent poison: half a grain occasions death in a rabbit in the course of five minutes. Its operation is always attended by symptoms of locked jaw.—4. *Brucia* occurs in the *Brucea antidysenterica*, and also in the nux vomica. It resembles strychnia in its properties, but is a much more virulent poison.—5. *Veratria* is the alkaline principle of the *Veratrum album*, or white hellebore, and of the *Colchicum autumnale*, or meadow saffron. It acts with great energy on the membrane of the nose, exciting violent sneezing. A few grains, taken internally, are fatal to the lower animals —6. *Emetia* is the alkaline principle of Ipecacuanha; *picrotoxia*, of the Cocculus Indicus; *solania*, of the Solanum dulcamara, or woody nightshade, &c. &c.

III. NEUTRAL SUBSTANCES.

341. *General Remarks.* — There are several vegetabl substances in which the oxygen and hydrogen exist in th same ratio as in water. These are *neutral* substances They occur in great abundance in the vegetable kingdom.

all the varieties of Coal and Bitumen. 1. *Coal* is known combustible, consisting of carbonaceous, bitun and various other matters. Of the common or *bla* there are several varieties. *Caking coal* is so name its particles softening by heat, and adhering together compact mass, or cake. *Splint coal* derives its nam its splintery fracture. *Cherry coal* has a slaty fractu is more easily broken than splint coal. *Cannel*, or *coal*, emits a brilliant light while burning, and ha used as a substitute for candles. *Glance coal*, or *anth* consists almost entirely of carbon, and contains no l nous matters. *Brown coal, bituminous wood*, or *brand*, resembles peat in the phenomena of its comb it presents the fibrous structure of wood. *Pitch c jet*, is intermediate between brown and black coal, used for making trinkets.—2. *Bitumen* is an inflan substance, resembling tar or pitch in its properties an Among the different bituminous substances, the *naphtha* and *petroleum* have been given to those wh fluid; *maltha*, to that which has the consistence of and *asphaltum*, to that which is solid.

V. SPIRITUOUS AND ETHEREAL SUBSTANCE

351. *Alcohol*.—Alcohol is the intoxicating ingred all spirituous and vinous liquors. Its composition same as that of the oils. Most saccharine substance under favourable circumstances, be readily convert fermentation, into alcohol. Alcohol is prepared fron tuous and vinous liquors by *distillation*. The annexed represents a large *still*, used in the distillation of ardent spirits. This apparatus consists of two vessels: one of these is composed of two parts, a body *a*, and a head *b*; the head is so shaped that the vapours which rise and are

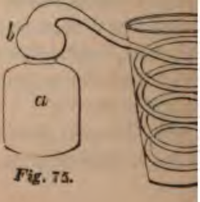
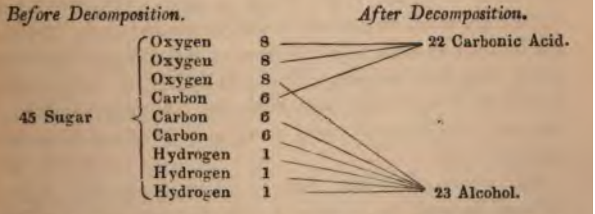


Fig. 75.

condensed against its sides, are conveyed by its curved beak into a spiral pipe, called the *worm*, which is immersed in a tub *d*, containing cold water. During their passage, the vapours are condensed, and flow out at the lower end of the worm in a liquid form. Common alcohol, or *spirit of wine*, is obtained by distilling whisky or some ardent spirit; *rectified spirit of wine* is procured by a second distillation; in both cases, the alcohol contains a certain quantity of water. The water may be entirely removed by some substance which has a strong affinity for it, as carbonate of potassa, or chloride of calcium; in this state, the spirit is termed *absolute alcohol*, to denote its entire freedom from water. Equal weights of absolute alcohol and water constitute *proof spirit.*

352. *Vinous Fermentation.*—The formation of *Alcohol* takes place during the process of *vinous fermentation.* This process depends upon the decomposition of *sugar*, the only substance which enters readily into a state of vinous fermentation. The composition of 45 parts of sugar is, oxygen 24, carbon 18, and hydrogen 3; and these are resolved, during fermentation, into 23 parts of alcohol, and 22 of carbonic acid. These *changes* are represented in the following *diagram*:—



353. *Ethers.*—Ethers are the volatile and fragrant fluids produced by heating acids with alcohol. Their names are derived from the acids with which they are formed, most of them containing the acid, or the elements of the acid, employed in their production; thus, we have sulphuric ether,

nbergris is considered to be a concretion formed in the omach of the spermaceti whale; it is found floating on the a near the coasts of India and Africa. *Butyrine* is a fatty atter contained in butter. *Hercine* is found in the fat of oats and of sheep. *Phocenine* occurs in the oil of the poroise. These last principles, when converted into soap, eld several acids.

III. SUBSTANCES WHICH ARE NEITHER ACIDS NOR FATS.

360. *Albuminous Principles.*—When any part of an animal ody is boiled in water, it is separated into two portions—he one soluble in water, and forming with the water a remulous jelly, or *gelatine;* the other remaining insoluble, ndeed becoming harder, the longer it is boiled; and from he identity of its properties with those of white of egg, deominated *albumen.* These two substances exist in very ifferent proportions in the different textures. 1. *Albumen* exists, in the *solid* state, commonly called *coagulated* alumen, in the cellular tissue, the skin, the vessels, &c.; in he *liquid* state, it occurs in the serum of the blood, and in certain animal secretions. The *curd* of milk is a modification f the albuminous principle.—2. *Gelatine* exists abundantly n the *solid* parts of the body, as the skin, cartilage, tendons, bones, &c.; it is not found in healthy animal fluids. Dr. Prout observes, that ‘Gelatine may be considered as the east perfect kind of albuminous matter existing in animal bodies: intermediate, as it were, between the saccharine principle of plants, and thoroughly developed albumen: indeed, gelatine in animals may be said to be the counterpart of the saccharine principle in vegetables; it being distinguished by its ready convertibility into a sort of sugar, by a process similar to that by which starch may be so converted.’ —3. *Fibrin* is another modification of the albuminous principle, existing in a suspended state in the blood, but more abundantly in the form of a tough fibrous mass, in which

lection of the products, constitute *destructive distillation.*

Ductility (*duco*, to draw). A property of some metals, by which they may be drawn out into wire.

Ebullition (*ebullio*, to bubble up). The production of vapour at the *boiling* point. See *Evaporation.*

Effervescence (*effervesco*, to grow hot). The commotion produced in fluids by the sudden escape of gas, as on pouring acid on chalk.

Efflorescence (*effloresco*, to blow as a flower). The pulverescence of crystals, as sulphate of soda, on exposure to the air. It is opposed to *deliquescence.*

Elasticity (ἐλαύνω, to push back). The property or power by which a body, when compressed or extended, returns to its former state. See *Gas.*

Electricity (ἤλεκτρον, amber). A fluid or property in nature which is called into action in its simplest form, by rubbing glass or amber. The terms introduced by Dr. Faraday are explained at page 79.

Elixir. An Arabic term for an *essence*, or pure mass without any dregs. A term formerly applied to compound tinctures.

Empyreumatic (ἐμπυρεύω, to set on fire). A term applied to the peculiar vapours produced by destructive distillation.

Equilibrium (*æquè*, equally, *libro*, to balance). A term expressive of the equality of temperature, which all bodies on the earth are constantly tending to attain; and of the equal distribution of the electric fluid in its natural undisturbed state. Forces which are thus equally balanced, are said to be *in equilibrio.*

Equivalent (*æquè*, equally, *valeo*, to avail). A term applied to the combining proportions of elementary and compound substances. It is frequently used in the same sense as the term *atom.*

Eudiometer (εὐδία, calm weather, μέτρον, a measure). An instrument for ascertaining the proportion of oxygen in a gaseous mixture.

Evaporation (*e*, from, *vapor*, vapour). The production of vapour at common or moderate temperatures.

Expansibility (*expando*, to spread out). The property by which a body is capable of occupying more space than it usually requires; it is called into action by heat.

Factitious (*factito*, to practise). Made by art, as factitious cinnabar, in distinction from the natural production. The term is also applied to waters prepared in imitation of natural waters, as those of Brighton.

Fermentation (*fermentum*, yeast). Certain changes of animal or vegetable substances, when reduced to the moist or liquid state by water. There are four kinds: 1, the *saccharine*, when the change terminates in sugar, as that of starch; 2, the *panary*, as that of flour forming bread, or the *vinous*, as that of the grape forming wine,—evolving alcohol; 3, the *acetous*, when the result is acetic acid, or vinegar; and, 4, the *putrefactive*, and whey. When milk is coagulated by means of rennet, a curdy substance, or the *caseous* principle, is produced; this is the basis of cheese in a state of purity. 6. *Mucus* is a peculiar transparent fluid, secreted by the surface of the *cellular membrane;* it consists chiefly of water, with muriate of soda, and a trace of albumen. 7. The fluid secreted by the *serous surfaces* consists principally of water, with small portions of albumen, mucus, and saline matter. 8. *Pus* is the fluid secreted by an inflamed and ulcerated surface. In the healthy state, it is a thin transparent fluid, with opaque globules floating in it. Pus varies much in its qualities, according to the nature of the source from which it is produced. 9. *Urine* is a transparent limpid fluid, with an acid reaction when recently excreted, but becoming afterwards alkaline. It contains nitrogen, in the form of highly azotized products, and various saline and earthy compounds. It is peculiarly prone to spontaneous decomposition.

RECAPITULATION.

357. What is *adipocere?* — 358. Enumerate some of the animal acids. — 359. State the analogy between the animal and the vegetable oils.—360. What are animal albumen, gelatine, and fibrin? What is glue? What is isinglass?—361. What are the chief constituents of the *Blood?*—What are the differences between *venous* and *arterial* blood?—362. What is meant by the term *secretion?* State the composition of saliva; of the pancreatic juice; of the gastric juice; of bile; of milk; of mucus; of pus; and of urine.

tain combinations of sulphur, from their *liver-like* appearance. Thus, we have liver of antimony, an oxy-sulphuret; liver of sulphur, or sulphuret of potash; hepatic air, or sulphureted hydrogen gas, &c.

Hermetic Seal (Ἑρμῆς, Mercury). The closing, air-tight, of the end of a glass tube or vessel when heated to the melting point. The name is derived from the Egyptian *Hermes*, supposed to have been the father of chemistry — hence called the *Hermetic art.*

Homogeneous (ὁμὸς, alike, γένος, kind). A term applied to substances composed of particles which are of the same nature, and have therefore the same properties. *Heterogeneous* (ἕτερος, other, γένος, kind) is a term applied to substances, the particles of which, and therefore the qualities, are of different kinds. Thus, in minerals, sandstone is a *homogeneous*, granite is a *heterogeneous*, substance.

Hydracids. *Hydro-acids.* A class of acid compounds, into which hydrogen enters as the acidifying principle.

Hydrates (ὕδωρ, water). Chemical compounds of solid bodies and water, still retaining the solid form. If water be not a constituent, the compound is said to be *anhydrous.*

Hygrometer (ὑγρὸς, moist, μέτρον, a measure). An instrument for ascertaining the degree of moisture of the atmosphere.

Hygrometric Water. That portion of moisture which gases yield to deliquescent salts.

Hyper (ὑπὲρ, over or above). This prefix is a Greek preposition, denoting *excess*, as in *hyper*-oxymuriatic acid, a compound containing *more* oxygen than oxymuriatic acid.

Hypo (ὑπό, under). This prefix is a Greek preposition, signifying *deficiency*, as in *hypo*-nitrous acid, a compound containing *less* oxygen than nitrous acid.

Ignition (*ignis*, fire). An effect of caloric, implying the emission of light from bodies which are much heated, without their suffering any change of composition. Bodies begin to become *ignited*, or red-hot, at about 800° F.; the highest point of ignition is a *white light.*

Impenetrability (*in*, not, *penetro*, to penetrate). The property by which a body occupies any space, to the exclusion of every other body. All bodies are impenetrable, what is called *penetration* being merely the admission of one substance into the *pores* of another.

Imponderables (*in*, priv., *pondus*, weight). Agents which are destitute of appreciable weight, as Light, Heat, Electricity.

Incandescence (*incandesco*, to grow hot). The glowing or shining appearance of heated bodies.

Incineration (*incinĕro*, to reduce to ashes, from *cinis*, a cinder). The reducing to ashes by burning. The combustion of vegetable or animal substances, for the purpose of obtaining their ashes or fixed residues.

Infusion (*infundo*, to pour on). The pouring of water, hot or cold, on vegetable substances, for the purpose of extracting their soluble and aromatic principles.

Insulation (*insula*, an island). A term applied to a body containing a quantity of electric fluid, and surrounded by non-conductors, so that its *communication* with other bodies is cut off, and the body *insulated*.

Integral Particles (*integer*, entire). The most minute particles, *similar to each other*, into which a substance can be divided. Thus, the smallest portion of powdered marble is still marble; but if, by chemical means, the calcium, the carbon, and the oxygen, of this portion be separated, we shall then have the *elementary* or constituent particles.

Isomorphous. This and some similar terms are sufficiently explained at page 133.

Lake. A term applied to certain insoluble compounds, formed by precipitating colouring matter with an earth or oxide. Almost all vegetable colouring matters may be precipitated into *lakes*, by means of alum or oxide of tin.

Lens (*lens*, a bean). A small roundish glass, shaped like a lentil, or bean. It is employed in fusing refractory substances; and for refracting rays of light, so that the divergence, or convergence, of those rays shall be equally produced after their passage through a lens.

Levigation (*lævigo*, to polish). The process of rubbing earths and some metallic substances with a *muller* upon a flat table of hard stone. Some fluid is added to assist the operation, which in this respect differs from *trituration*.

Liquefaction (*liquefacio*, to melt). The passing of a substance from the solid to the *liquid* state—one of the effects of caloric. *Liquids* are fluids whose elasticity is inactive, and the cohesion of whose particles towards each other is less than their individual gravities; so that they separate by their own weight, and may then be divided drop by drop.

Litharge (λίθος, a stone, ἄϱγυϱος, silver). An oxide of lead in an imperfect state of vitrification. Litharge is more or less white or red, according to the metals with which the contained silver is alloyed, the white being called *litharge of silver*, the red *litharge of gold*.

Lixiviation (*lixivium*, a ley). The solution of an alkali or of a salt in water, in order to obtain the soluble portion in the form of a *lixivium*, or ley.

Lute. A paste made of clay, sand, and other materials, for closing the joinings of retorts, receivers, &c., for the purpose of rendering them air-tight.

Maceration (*macero*, to make soft by steeping). The steeping of a body in a cold liquid, in order to soften it.

Magistery (*magister*, a master). A *masterly* preparation; a term formerly applied to almost all precipitates.

Magnetism. A peculiar property of certain bodies, particularly iron, by which, under

Atmosphere (*ἀτμὸς*, vapour, *σφαῖρα*, a sphere). The volume of air which surrounds the earth.

Atom (*α*, priv., *τέμνω*, to cut). That which cannot be divided; an ultimate particle of matter.

Attraction (*attraho*, to draw to). The tendency which bodies have to be drawn to each other. It differs from *gravity* in being a more general term: gravity is a *species* of attraction.

Azote (*α*, priv., *ζωὴ*, life). Life-depriver; a term applied to *nitrogen*, from its being incapable, alone, of supporting life.

Barometer (*βάρος*, weight, *μέτρον*, a measure). A weather-glass; an instrument for measuring the varying pressure of the atmosphere.

Basis (*βάσις*, a base). 1. The substance with which an acid is combined in a salt. 2. A *mordaunt*; a substance used in dyeing, which has an affinity both for the cloth and the colouring matter.

Bi (*bis*, twice). A prefix signifying that the *base* is contained in a compound in *two* definite proportions.

Bittern. The *mother water*, or uncrystallizable residue left after muriate of soda has been separated from sea-salt by crystallization.

Calcareous (*calx*, lime). The name of a class of earths, consisting of lime and carbonic acid, as chalk, marble, &c.

Calcination (*calx*, lime). The process of forming a *calx*, or oxide, by exposure to intense heat in the open air.

Caloric (*calor*, heat). An imaginary fluid substance supposed to be diffused through all bodies, and producing the sensible effect of *heat*.

Caustic (*καίω*, *καύσω*, to burn). A substance which destroys parts by chemically decomposing them.

Cementation. A process by which the properties of a body are changed, on being surrounded by other bodies in a state of powder, and exposed to a high temperature, as in the conversion of iron into steel by cementation with charcoal.

Chalybeate (*Chalybes*, a people who dug iron out of the earth). The name of waters which contain iron.

Chemical Combination. The intimate union of two bodies, which forms a compound differing in one or more qualities from either of the constituent bodies.

Cohesion (*cohæreo*, to cling together). The species of attraction by which the component parts of a body *cohere*, or are kept together. It is the antagonist of *expansion*.

Concentration. The strengthening of solutions, mixtures, &c., by evaporation of their watery parts.

Condensation (*condenso*, to make thick). The act of diminishing the bulk of a body, as by the conversion of steam into water, gases into liquids, liquids into solids. When this is done by external force, it is termed *compression*.

Congelation (*gelu*, cold). The thickening, or solidification, wholly or in part, of a liquid.

Thus, water *congeals*, and becomes ice; the skins of animals, when dissolved in water by boiling, *congeal*, and become glue.

Crepitation (*crepito*, to crackle). The crackling sound occasioned by certain salts during calcination.

Crocus (saffron). A term formerly applied to some preparations, from their yellow or *saffron* colour.

Crucible (*crux*, a cross, which the alchemists stamped upon the vessel; or *crucio*, to torture). A chemical vessel in which the metals were *tortured*, to force them to become like gold. See page 191.

Cryophorus (κρύος, cold, φέρω, to bring). An instrument for exhibiting the degree of cold produced by evaporation. See page 46.

Crystallization (κρύσταλλος, a crystal). The process by which the particles of liquid or gaseous bodies form themselves into *crystals*, or solid bodies of a regularly limited form.

Cupel (*kuppel*, German, a cup). A small flat, *cup*-like crucible, made of bone ash.

Cupellation. The process of purifying gold and silver by melting them with lead, which is first oxidated, then vitrified, and sinks into the *cupel*, carrying along with it all the baser metals, and leaving the gold or silver upon its surface.

Decrepitation (*de*, from, *crepito*, to crackle). The crackling noise which takes place when certain bodies, as salts, are heated.

Deflagration (*deflagro*, to burn). The oxidation of metals by mixing them with nitrate or chlorate of potash, and projecting the mixture into a red-hot crucible.

Deliquescence (*deliquesco*, to melt). The property of some salts of attracting moisture from the air, and becoming liquid.

Density (*densus*, thick). A relative term, denoting the comparative quantity of matter in different bodies, which is contained in the same space. See *Volume*.

Deoxidation. The process of depriving a substance of the *oxygen* which it contains.

Dephlogisticated (*de*, from, *phlogiston*, the inflammable principle). Deprived of phlogiston; oxidized. See *Phlogiston*.

Deutoxide (δεύτερος, second). A term applied to a substance which is in the *second* degree of oxidation.

Diaphanous (διὰ, through, φαίνω, to shine). The name of bodies which *transmit light* through their substance.

Diathermanous (διὰ, through, θέρμη, heat). The name of bodies which *transmit heat* through their substance.

Digester. A strong vessel of copper or iron, for preventing the loss of heat by evaporation.

Digestion. The continued action of a solvent upon any substance.

Distillation (*distillo*, to drop by little and little). The process of converting a liquid into vapour by means of heat, and of reconverting the vapour into liquid by means of cold. The subjection of bodies to a red heat in close vessels, and the col-

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